Sandia Corporation
Albuquerque, New Mexico
December 15, 2006

DOE/Sandia Responses to NMED's "Notice of Disapproval: Mixed Waste Landfill Corrective Measures Implementation Work Plan, November 2005"

Comment Set 1

INTRODUCTION

This document responds to the first set of comments received in a letter from the New Mexico Environment Department (NMED) to the U.S. Department of Energy (DOE) and Sandia Corporation (Sandia) on November 24th, 2006 regarding the Mixed Waste Landfill (MWL) Corrective Measures Implementation (CMI) Plan for Sandia National Laboratories (SNL). The letter is entitled "Notice of Disapproval: Mixed Waste Landfill Corrective Measures Implementation Work Plan, November 2005, and Requirement for Soil-Vapor Sampling and Analysis Plan, Sandia National Laboratories" [EPA ID NM5890110518, HWB-SNL-05-025].

The NMED letter contains two sets of comments, divided based on subject. The first set is entitled, "Part 1, Comments on Landfill Construction Plans and Performance Modeling". The second set is entitled, "Part 2, Comments on the MWL Fate and Transport Model (Appendix E)". The NMED letter also includes a request for a Soil-Gas Sampling Plan to obtain more current soil gas data.

This response document provides the first set of NMED comments, and DOE/Sandia's responses. NMED comments are listed in boldface, followed by the DOE/Sandia response, written in normal font under "Response". This document also contains a sampling and analysis plan (SAP) requested by NMED to obtain more current data on volatile organic compounds (VOCs), tritium, and radon at the MWL. The SAP is presented in Appendix A.

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under Contract DE-AC04-94AL85000.

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Part 1. Comments on Landfill Construction Plans and Performance Modeling

1. -- Executive Summary, Page iii, last bullet -- Define the term "climax ecological community".

<u>Response:</u> The term “climax ecological community” is a term for a late or final stage in the development of an ecological community in which the composition of plants and animals is relatively stable and well-matched to environmental conditions. In the case of the MWL, the climax ecological community would be classified as Desert Grassland (Dick-Peddie, 1992), under current climatic conditions.

2. Section 2.1 -- Provide a more detailed schedule that, at a minimum, indicates completion times for the following cover and project elements: subgrade, bio-intrusion barrier, native soil layer, topsoil layer, seeding, fencing, overall completion of project, and submittal of Corrective Measures Implementation (CMI) Report to NMED. As the actual start time is dependent on when the CMI Plan is approved, the completion times can be proposed as the number of days from the start time (assume the start time = 0 days).

<u>Response:</u> A detailed schedule for the cover construction activities is presented below. Subgrade preparation activities should be completed by December 31, 2006. The cumulative schedule assumes approval to install the cover is received at start time T=0 days (T_0). Assumptions include the following:

1) NMED approves the SAP for soil gas VOCs, tritium, and radon at the MWL within fifteen days of receiving the document, allowing rapid implementation of the soil gas sampling activities.

2) DOE/SNL complete the soil gas and tritium sampling activities by mid-January, and cover construction activities are initiated shortly thereafter, allowing the current MWL field crew and heavy equipment to be retained.

3) The cover start time T_0 assumes full NMED approval of the MWL cover design presented in the CMI Plan (SNL/NM November 2005), as well as approval of the DOE/SNL responses to the Part 1 NOD comments.

TASK	Task Duration (Working Days)	Cumulative Time From T_0 (Calendar Days)
Receive Approval To Install Cover (T_0)	**0 days**	**0**
Screen Native Soils at the Borrow Areas	50 days	78
Extend MWL-MW4 Well Casing; Service Pump and Packer	20 days	44
Haul and Place Bio-Intrusion Barrier Rock	45 days	62
Haul Native Soil from Borrow Areas to MWL	30 days	47
Place Native Soil Layer	50 days	132
Procure 3/8" Crushed Gravel for Topsoil Layer	20 days	103
Stockpile Topsoil	14 days	93
Blend 3/8" Gravel with Topsoil	15 days	118
Haul and Place Topsoil Layer	30 days	190
Seed Cover and Surrounding Area	10 days	204
Install Fencing	10 days	218
Demobilize	20 days	225
Overall Completion of the Cover Construction Project	209 days	225
Submit Corrective Measures Implementation Report to NMED	130 days[2]	407

[1]Subgrade preparation should be completed by 12/31/2006
[2]180 calendar days

3. Section 5.2.2.1.1, last paragraph -- Describe the rainfall event that was simulated in the second in situ test.

Response: A short-duration rainfall-simulation study was undertaken in 1998 to estimate evapotranspiration rates following natural rainfall events, and to provide infiltration and percolation data useful for fitting unsaturated models (SNL, April 1999; Wolford, 1998). A 10 ft by 10 ft plot was established approximately 100 ft northwest of the MWL IP test plot, located approximately 500 ft west of the MWL. A neutron access tube was installed in the center of the plot, and initial moisture contents were measured using gravimetric samples and neutron logging prior to initiating the rainfall event.

The simulated rainfall event consisted of applying 80 gallons (303 liters) of water, equal to 1.28 inches over 100 ft2, to the plot over a period of 38 minutes during the afternoon of August 20, 1998. The water was distributed uniformly over the plot by subdividing the plot into 4 quarters, and sprinkling from a hose for known time periods on each section of the plot.

The soil within the plot was subsequently sampled at 3-inch depth increments between August 20 1998 and September 30, 1998 to obtain soil-water content values over time following application of the water. The data collected were used to fit infiltration and unsaturated flow parameters, as well as to estimate evapotranspiration rates for modeling purposes. Additional details on the artificial rainfall experiment simulated in the second in situ test are presented in Wolford, 1998.

4. Section 5.2.2.2, 1st paragraph on page 5-4 -- Specify whether the degree of compaction was measured using the standard or modified proctor test.

Response: The degree of compaction was measured using Standard Proctor tests. The results are tabulated in Attachment C of Appendix A, “Geotechnical Report”, in the document, "Deployment of an Alternative Cover and Final Closure of the Mixed Waste Landfill, Sandia National Laboratories, New Mexico" (SNL September 1999).

5. Section 5.3.2.4, next to last sentence —This sentence refers to a sand layer with an initial water content of 0.036 cubic centimeters being used for a boundary condition, Normally, water content of soil is expressed as a percentage (of the ratio of the mass of water per the mass of solids, or in the case of volumetric water content the ratio of the volume of water to the total volume of soil). Confirm whether this value and unit of measurement are correct.

Response: The units for initial water content in the next-to-last sentence in Section 5.3.2.4 were incorrect. This sentence should read, “Instead, a coarse sand layer with an initial water content of 0.036 cm^3/cm^3 was used for its lower boundary condition”.

The text in this section has been revised accordingly.

6. Section 5.7.1 -- Specify the values used for the variables R, K, LS, VM and sources of the values used in the MUSLE equation to predict soil loss by water erosion.

Response: The calculation set for potential soil loss from the MWL cover using the Modified Universal Soil Loss Equation (MUSLE) was originally presented in Appendix D of the document, “Deployment of an Alternative Cover and Final Closure of the Mixed Waste Landfill, Sandia National Laboratories, New Mexico” (SNL/NM September 1999). A copy of this calculation set, entitled “Erosion and Slope Stability Calculations”, is included as Attachment 1 to this NOD response. This calculation set includes copies of the tables and figures from which the variables R, K, LS, and VM were determined.

References used to prepare this calculation set include

- Geotechnology of Waste Management, 2nd Ed., Issa S. Oweis, Raj P. KHera, February, 1998.
- AGRA, Mixed Waste Landfill Cover, Tabulation of Test Results performed by AGRA Earth & Environmental on May 17, 1999.

Values used for the variables and sources for the values are shown in the table below.

Parameter	Variable	Value	Additional Information
Rainfall Factor	R	35	Determined from isoerodent map of the western United States, illustrating average annual values of the rainfall factor, R. See Figure 1, Sheet 9 of Attachment 1.
Soil Erodibility Factor	K	0.44	Approximate value of K, based on a loamy very fine sand with organic content < 0.5%. See tabulation of AGRA test results, Table 1, Sheet 10 of Attachment 1; K determined from Table 2, Sheet 12, of Attachment 1.
Topographic Factor for Cover (2% slope)	LS	0.28	See Sheets 5 and 6 of Attachment 1.
Topographic Factor for Sideslope (16.7% slope)	LS	1.32	See Sheets 5 and 6 of Attachment 1.
Erosion Control Factor for Cover (no vegetation)	VM	0.06	Assumes no vegetation was yet established; that straw mulch had been applied to the cover and side-slopes at 2 tons/acre, and that the mulch was crimped into soils with a disk. See Sheet 7 and Sheet 14 of Attachment 1.
Erosion Control Factor for Sideslope (no vegetation)	VM	0.11	Assumes no vegetation was yet established; that straw mulch had been applied to the cover and side-slopes at 2 tons/acre, and that the mulch was crimped into soils with a disk. See Sheet 7 and Sheet 14 of Attachment 1
Erosion Control Factor for Cover and Sideslope (vegetation established)	VM	0.01	Assumes that vegetation is established on both the cover and side-slopes 12 months after seeding, and assumes that one-half the straw mulch remained. See Sheet 8 and Sheet 15 of Attachment 1.

7. Section 5.7.2 -- Specify the values used for the variables I, k, C, L, V and sources of the values used in the WEQ equation to predict soil loss by wind erosion.

<u>Response:</u> The calculation set for potential soil loss from the MWL cover using the Wind Erosion Equation (WEQ) was originally presented in Appendix D of the document, "Deployment of an Alternative Cover and Final Closure of the Mixed Waste Landfill, Sandia National Laboratories, New Mexico" (SNL/NM September 1999). A copy of this calculation set, entitled "Erosion and Slope Stability Calculations", is presented as Attachment 2 to this NOD response. This calculation set includes copies of the tables and figures from which the variables I, k, C, L, and V were determined.

References used prepare this calculation set include

- Natural Resources Conservation Service (NRCS) National Agronomy Manual, 190-V-NAM, 2nd Ed., Part 502, March 1988.

- 2) N.P. Woodruff and F.H. Siddaway, 1965. "A Wind Erosion Equation," Soil Science Society of America Proceedings, Vol. 29, No. 5, Pages 607-608.

Values used for the variables and sources for the values are shown in the table below.

Parameter	Variable	Value	Additional Information
Soil Erodibility Index for Cover (2% slope)	I	134 tons/acre/year	Based on erodibility index for a loamy very fine sand, as determined by AGRA test results. See Sheet 2, 9 and 11 of Attachment 2.
Soil Erodibility Index for Sideslope (16.7% slope)	I	188 tons/acre/year	Based on erodibility index for a loamy very fine sand, as determined by AGRA test results. See Sheets 3, 9 and 11 of Attachment 2.
Total Surface Roughness (Cover and Sideslope)	k	1.0	Based on the assumption that the engineered cover and sideslopes will be smooth and without ridges. See Sheets 3, 4, 13 and 14 of Attachment 2.
Climatic Factor	C	120	Index of the relative erosivity by geographic location. See Sheets 5 and 15 in Attachment 2.
Unsheltered Distance (Cover)	L	524 ft	Field length along the prevailing wind direction. See Sheets 5 and 15 of Attachment 2.
Unsheltered Distance (Sideslope)	L	25 ft	Field length along the prevailing wind direction. See Sheets 5 and 15 of Attachment 2.
Vegetative Cover Factor (Cover)	V	4,500 small grain equivalent	Assumes no vegetation was yet established; that straw mulch had been applied to the cover and side-slopes at 2 tons/acre, and that the mulch was crimped into soils with a disk. See
Vegetative Cover Factor (Sideslope)	V	3,200 small grain equivalent	Assumes vegetation is established on cover and sideslopes 12 months after seeding, and one half the straw mulch remains. Also assumes that 400 small grain equivalent of native grass is established on cover and sideslopes.

8. Section 7.0 -- The NMED expects the vadose zone to be monitored for volatile organic compounds, tritium, and radon, in addition to soil moisture. The NMED may also require soil-gas monitoring to be conducted at depths other than at 173 feet, as implied by the Permittees in the second paragraph of Section 7.1. Monitoring details will need to be included in the long-term monitoring and maintenance plan, due within 180 days following approval of the CMI Report. No response is required at this time.

Response: DOE/Sandia are proposing a robust soil-gas monitoring system for long-term monitoring at the MWL. The soil-gas monitoring system will serve as an early-warning system to protect groundwater from potential migration of contaminants. Additional information regarding the proposed monitoring, including the parameters and depths to be monitored, will be included in the DOE/Sandia responses to the second set of comments within this NOD (Part 2). Further details will be included in the Long Term Monitoring and Maintenance Plan (LTMMP), to be submitted within 180 days of the NMED's approval of the MWL CMI Report.

9. Figure 5-1 -- Clarify which curves are representative of the PET data from the four National Weather Service stations in New Mexico and which are representative of the predicted PET data.

Response: The PET curves for the Cochiti, Elephant Butte, Socorro, and Bosque del Apache National Weather Service Stations are delineated by wider lines and have no symbols. The curves representing the PET data predicted by HELP-3 are delineated by much narrower lines, and have symbols identifying the monthly PET values predicted by the model.

10. Appendix A, Construction Specifications, Section 02930, Reclamation seeding and Mulching, Part 3.1.2, #1 -- Explain why the TA-3 borrow pits are not to be reseeded by the contractor, given that erosion of the borrow pits should be prevented.

<u>Response:</u> Once the MWL cover has been constructed and the TA-3 borrow pits are no longer required for environmental restoration activities, they may be transferred over to Sandia Facilities for continued use at Sandia. However, if the TA-3 borrow pits are not needed by Facilities, they will be seeded and reclaimed as described in Appendix A, Construction Specifications, Section 02930, Reclamation Seeding and Mulching.

11. Appendix A, Construction Specifications, Section 02200, Earthwork Part 3.3.3, #4 -- The Permittees should consider changing the requirement that no proof rolling be conducted within 2 feet of any groundwater monitoring well, measuring device, or other placed surface. The NMED strongly suggests changing the requirement to preclude all heavy equipment from operating within 3 feet of wells or other measuring devices.

<u>Response:</u> The requirement will be changed to preclude all heavy equipment from operating within 3 feet of any monitoring well or measuring device.

12. Appendix A, Construction Specifications, Section 02200, Earthwork Part 3.3.4, #8 and Part 3.3.6., #9 -- Both of these sections contain language stating that nonconforming work shall be redone until the specifications are attained "or the Operator accepts the placement conditions". Please note that the NMED expects construction of the cover to comply substantially with the specifications in the approved CMI Plan. Failure to achieve the specifications in the approved CMI Plan, or obtain an NMED-approved change, could lead to disapproval of part or all of the constructed cover.

<u>Response:</u> Sandia fully expects to construct the MWL cover to meet all specifications identified in the CMI Plan. If these specifications cannot be met for any reason, the NMED will be informed of these discrepancies and a mutually-acceptable corrective action will be determined and implemented.

13. Appendix A, Construction Specifications, Section 02200, Earthwork Part 3.3.6 -- The NMED strongly recommends that the Permittees add to the specifications for construction of the native soil layer a requirement for a minimum number of passes with compaction equipment.

<u>Response:</u> Part 3.3.6 of Section 02200 describes the installation of the native soil layer. Item 5 of Part 3.3.6 states that for each lift "The Contractor shall compact to not less than 90 percent of maximum dry density at -2 to +2 percentage points of optimum moisture content, as determined by ASTM D698 (Standard Proctor testing)." Item 9 of the same section further states that "Lifts not compacted to the density and moisture content specifications or not meeting the requirements of this specification shall be reworked to the full depth of the lift and recompacted until the specifications are attained or the Operator accepts the placement conditions."

With the requirement that the lifts be compacted, and tested to meet a specified compaction, it is not necessary to count the number of passes of compaction equipment, as long as the construction specifications are met.

14. Appendix B, Construction Quality Assurance Plan, Section 2.6.3, first sentence — Clarify what is meant by the first sentence: "The CQA Certifying Engineer is responsible for...certifying the CQA document has been approved by the NMED". Did the Permittees intend, instead, to require that the CQA Certifying Engineer be responsible for certifying the results of the CQA Report that is to be submitted for NMED approval? If so, the first sentence should be revised to state "The CQA Certifying Engineer is responsible for certifying in a statement to the owner and the NMED that, in his or her opinion, the cover has been constructed in accordance with all plans and specifications". The next sentence of the paragraph explains further that the certification statement would normally be included in a CQA Report.

Response: The first sentence will be revised to state "The CQA Certifying Engineer is responsible for certifying in a statement to the owner and the NMED that, in his or her opinion, the cover has been constructed in accordance with all plans and specifications."

15. Appendix B, Construction Quality Assurance Plan, Section 8.7 -- The Final Report must be submitted to the NMED as part of the CMI Report. The Final Report must include copies of all quality control data generated by the construction contractor as well as the quality assurance data generated by the CQA contractor.

Response: The Construction Quality Assurance **Report** will include all quality control data generated by the construction contractor as well as quality insurance data generated by the CQA contractor. The Construction Quality Assurance **Report** will be submitted to the NMED as part of the CMI Report.

16. Demonstrate with calculations and other information whether run-off and run-on controls have been adequately designed to handle peak precipitation events. Evaluate and discuss whether additional run-on controls should be constructed at locations further away from the landfill (e.g., at distances of 25 to 50 meters) to provide more protection for the cover from heavy rainfall events.

Response: Calculations have been prepared regarding the adequacy of the run-off and run-on controls for handling peak precipitation events. The complete calculation set and supporting exhibits are presented in Attachment 3. The calculation results are summarized below.

The site will be graded such that runoff from the site flows north, west and east. There is a high point on the north side of the site that prevents flow from running onto the site. Two swales will be provided to carry the flow to the north or the south. This may be seen in Exhibit 1: Mixed Waste Landfill Final Cover Grading Plan", included in the complete calculation set (Attachment 3).

The watershed basin draining onto the site has been delineated and is shown on Exhibit 2 of Attachment 3. It is divided in to a north basin and a south basin that drain to the north and south swales respectively.

Runoff was calculated using the City of Albuquerque Development Process Manual (City of Albuquerque 2006) criteria for the 100 year –6 hour storm. The north basin generates 24 cfs and the north swale has the capacity for 79 cfs. The south basin generates 6.5 cfs and the capacity of the south swale is 58 cfs.

The swales are therefore sized with abundant capacity to prevent flow from entering the site and to carry the runoff around the site.

The general drainage pattern in this area is a gentle slope to the west. After the flow is discharged from the site, it drains westward and no additional controls are needed. Exhibit 2 shows the topography up to a minimum of 200 feet beyond the site to illustrate this.

17. Identify the criteria to be applied to determine whether the establishment of vegetation on the final cover is acceptable, including, but not limited to, species diversity, plant survival, and the extent of ground cover. Explain how measurements will be conducted in the field to assess these criteria.

Response: Establishment of the desired vegetation community on the MWL cover is anticipated to be the result of a successional process. Ecological succession is a generally predictable pattern of orderly changes in the composition or structure of an ecological community. Succession on the MWL will be initiated by the formation of this new, unoccupied habitat on the cover.

The MWL cover will be seeded with grass species that have been identified as native to the surrounding area. These grasses will eventually out-compete the weedy plants that dominate early in plant community succession. The final cover soil has been collected from the local area in order to provide the correct growing substrate for the seeded plant species. This soil is expected to contain a significant amount of weed seed, including large amounts of *Salsola tragus* seeds, commonly known as Russian thistle or tumbleweed. No supplemental watering is planned for the MWL, although supplemental watering is widely recommended to facilitate establishment of native plants in a chosen area. Due to a large amount of weed seeds and no supplemental watering, the early succession period is anticipated to be long.

Mature Plant Community Criteria

Vegetation on the MWL cover will be surveyed by a qualified biologist on a regular basis. This survey will include:

- Identification of any barren areas
- Identification of all plant species present on the cover

- Quantification of plant species present on the cover

Plant species will be identified according to their scientific names. Plant species will be quantified by determining the percent cover of each actively photosynthesizing species contained within a one-meter by one-meter survey quadrat. These quadrat survey locations will vary across the cover at the time of each inspection in order to best reflect plant cover across the MWL.

The mature, secondary plant community will be achieved when greater than 50% of the photosynthesizing foliar coverage is comprised of grass species native to the general TA-III area.

General Comments and Requirements for Soil-Gas Sampling

As the Permittees are aware, most site characterization data for the MWL (other than groundwater data) dates before the mid 1990's. Because the rupturing of containers and the leaking of their contents could have occurred since the mid 1990's, the NMED requires more current soil-gas data to help resolve this issue. The Permittees shall therefore collect and analyze active soil-gas samples taken at depths of 10 and 30 feet at a minimum of three locations within the landfill where previous sampling has detected the highest soil-gas concentrations in the past. The soil-gas samples shall be analyzed for volatile organic compounds, tritium, and radon. Pursuant to Section VI.A of the Order on Consent (April 29, 2004), the Permittees shall provide for approval to the NMED within 30 days of receipt of this letter a work plan to conduct the active soil-vapor sampling described above. The work plan shall be prepared in accordance with Section X.B of the Consent Order.

Response: A work plan has been developed which presents plans for sampling and analysis of soil gas at six locations within or adjacent to the MWL, and at two background locations. Soil gas samples will be collected at depths of 10 and 30 feet, and analyzed for VOCs. Soil samples will be collected from the same locations and depths, and analyzed for tritium in soil moisture. Samples for analysis of radon are difficult to obtain from soil gas samples; instead, radon sampling is proposed to be conducted along the MWL perimeter once the MWL cover has been completed.

The sampling and analysis plan for soil gas VOCs and tritium and radon is presented in Appendix A.

References

City of Albuquerque, 2006, "Albuquerque Development Process Manual", October 2006 Revision, published by American Legal Publishing Corporation, 432 Walnut Street, Cincinnati, Ohio 45202.

Dick-Peddie, W.A. 1992, "New Mexico Vegetation Past, Present and Future." University of New Mexico Press, Albuquerque, NM. 244 pp.

Sandia National Laboratories/New Mexico (SNL/NM), September, 1999, "Deployment of an Alternative Cover and Final Closure of the Mixed Waste Landfill, Sandia National Laboratories, New Mexico", prepared for US DOE by Sandia National Laboratories Environmental Restoration Project, Albuquerque, New Mexico, September 23, 1999.

Sandia National Laboratories/New Mexico (SNL/NM), November 2005. "Mixed Waste Landfill Corrective Measures Implementation Plan", prepared at Sandia National Laboratories by J. Peace, T. Goering, C. Ho and M. Miller for the U.S. Department of Energy, Albuquerque, NM.

Wolford, R.A., 1998, Preliminary unsaturated flow modeling and related work performed in support of the design of a closure cover for the Mixed Waste Landfill. Prepared by GRAM, Inc. for the Mixed Waste Landfill Cover Project, Environmental Restoration Program, Organization 6135. Sandia National Laboratories, Albuquerque, NM, November 10, 1998.

Attachment 1

Universal Soil Loss Calculations for the MWL Cover

Using the

Modified Universal Soil Loss Equation (MUSLE)

By: M. McVey	Date: 8/19/99	Title: Potential Soil Loss from the MWL Cover by Overland Runoff
Chkd. By: J. Peace	Date: 8/20/99	

Purpose:

Determine the soil loss due to sheet and rill erosion for the Mixed Waste Landfill alternative cover. The soil loss will be calculated by the Modified Universal Soil Loss Equation (MUSLE). This calculation only presents potential loss.

References:

1. Geotechnology of Waste Management, 2nd Ed., Issa S. Oweis, Raj P. Khera, February, 1998.
2. AGRA, Mixed Waste Landfill Cover, Tabulation of Test Results performed by AGRA Earth & Environmental on May 17, 1999.

Soil Loss Calculations

Modified Universal Soil Loss Equation (MUSLE):

$$A = RK(LS)(VM)$$

Where:

A = Average annual soil loss (Tons/Acre/yr.)

R = Rainfall factor

K = Soil erodibility factor

LS = Topographic factor

VM = Erosion control factor

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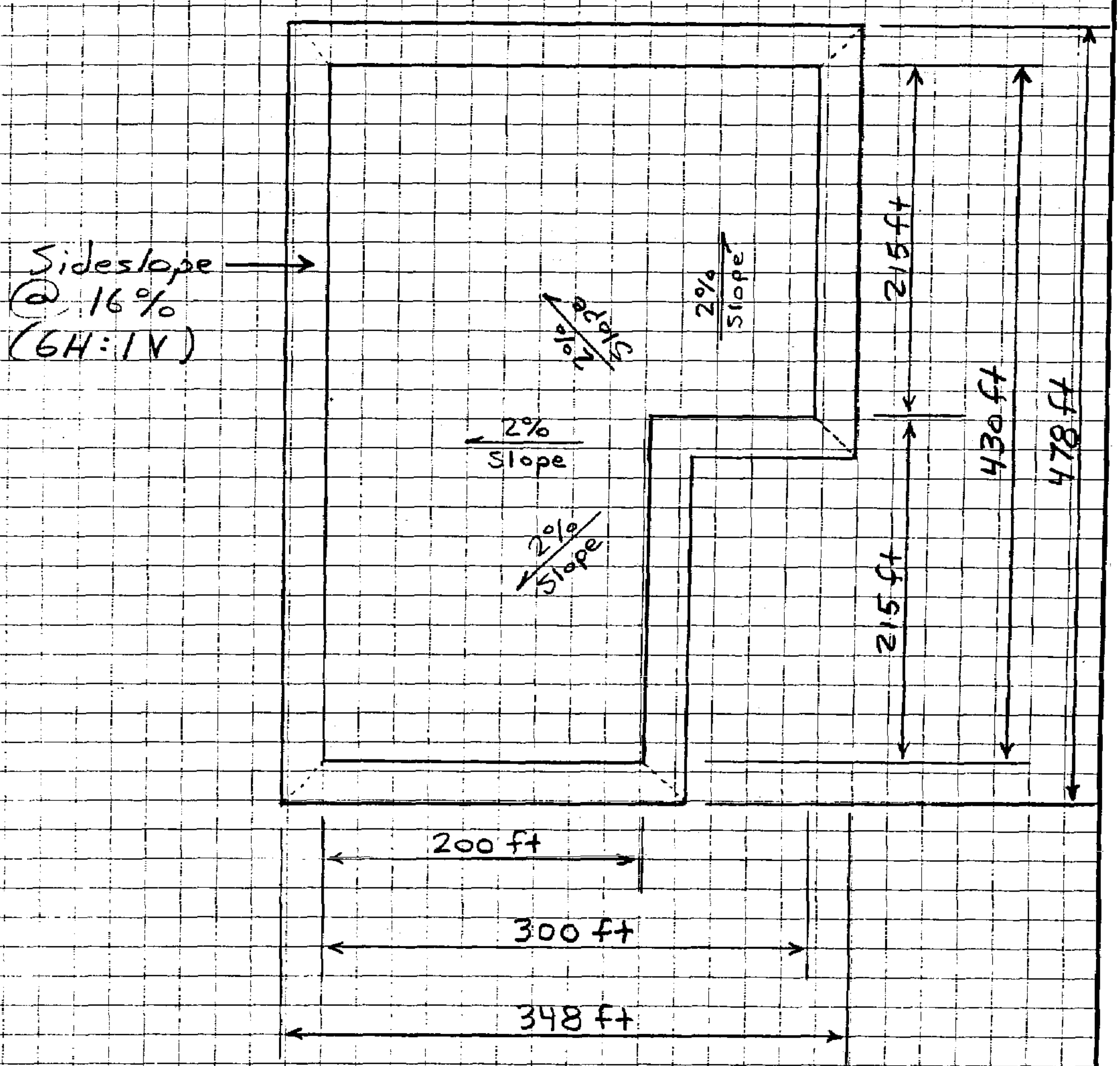
Plan View Cover



GRAM, Inc.

Calculation Sheet

By: M. McVey	Date: 8/19/99	Title: Potential Soil Loss from the MWL Cover by Overland Runoff
Chkd. By: J. Peace	Date: 8/20/99	

Area of Cover

$$A_c = (200\,ft \times 215\,ft) + (200\,ft \times 215\,ft) + (100\,ft \times 215\,ft)$$
$$= 107{,}500\,ft^2$$
$$= 107{,}500\,ft^2 / 43{,}560\,ft^2/Acre$$
$$= \underline{\underline{2.47\ Acres}}$$

Area of Sideslopes

$$A_{ss} = (24\,ft \times 478\,ft) + (24\,ft \times 200\,ft) + (24\,ft \times 239\,ft) + (24\,ft \times 100\,ft) + (24\,ft \times 215\,ft) + (24\,ft \times 324\,ft)$$
$$= 37{,}344\,ft^2 / 43{,}560\,ft^2/Acre$$
$$= \underline{\underline{0.86\ Acres}}$$

Total Area of Cover and Sideslopes

$$A_{TOT} = A_c + A_{ss}$$
$$= 2.47\ Acres + 0.86\ Acres$$
$$= \underline{\underline{3.33\ Acres}}$$

By: M. McVey	Date: 8/19/99	Title: Potential Soil Loss from the MWL Cover by Overland Runoff
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1) Determine rainfall factor, R:
From Figure 1 (Sheet 9)
$\Rightarrow R = 35$

2) Determine soil erodibility factor, K:
- From Tabulation of AGRA Test Results, Table 1 (Sheet 10); USCS Classifation = SM
- USDA classification for SM with sand fraction > 70% is loamy sand, Figure 2 (Sheet 11).
- Percent passing #170 sieve indicates that sand fraction is predominantly fine to very fine.

$\Rightarrow$ Loamy very fine sand

From Table 2 (Sheet 12), K for a loamy very fine sand with organic content < 0.5%
= 0.44

$K = 0.44$

By: M. McVey	Date: 8/19/99	Title: Potential Soil Loss from the MWL Cover by Overland Runoff
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3) Determine topographic factor, LS:

$$LS = \frac{(L/72.6)^m(65S^2 + 450S + 650)}{(S^2 + 10{,}000)}$$

where:

L = Slope length (See sheet 13)

S = slope steepness (%)

m = exponent

0.20 for $S < 1$

0.30 for $1 < S < 3$

0.40 for $3 < S < 5$

0.50 for $5 < S < 10$

0.60 for $S > 10$

$$LS_{(2\%)\,\text{cover}} = \frac{(327/72.6)^{0.3}(65(2)^2 + 450(2) + 650)}{(2)^2 + 10{,}000}$$

$$= \underline{\underline{0.28}}$$

for:

L = 327 ft

S = 2%

m = 0.30

By: M. McVey	Date: 8/19/99	Title: Potential Soil Loss from the MWL Cover by Overland Runoff
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$$LS_{(16.7\%)\ \text{Sideslopes}} = \frac{(24/72.6)^{0.6}\left(65(16.7)^2 + 450(16.7) + 650\right)}{(16.7)^2 + 10{,}000}$$

$$= \underline{\underline{1.32}}$$

for:

$L = 24$ ft (See sheet 13)

$S = 16.7\%$

$m = 0.60$

MUSLE:

$$A = RK(LS)(VM)$$

$$A_{(2\%\ \text{Cover})} = 35(0.44)(0.28)(VM)$$

$$= \underline{\underline{4.31(VM)}}$$

$$A_{(16.7\%\ \text{Sideslopes})} = 35(0.44)(1.32)(VM)$$

$$= \underline{\underline{20.33(VM)}}$$

By: M. McVey	Date: 8/19/99	Title: Potential Soil Loss from the MWL Cover by Overland Runoff
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4) Determine erosion control factor, VM:

Case 1 : No vegetation yet established, straw mulch applied to cover and sideslopes at 2 tons/acre, crimpted into soils with disk.

From Table 3 (Sheet 14)

$\Longrightarrow VM_{(2\%\ Cover)} = 0.06$

$\Longrightarrow VM_{(16.7\%\ Sideslopes)} = 0.11$

For 2% Cover Slope

$A = 4.31(0.06) = 0.26$ Tons/acre/yr.

For 16.7% Sideslopes

$A = 20.33(0.11) = 2.24$ Tons/acre/yr.

$$\text{Total Soil Loss} = \frac{(0.26\ Tn/Ac/Yr)(2.47\ Ac) + (2.24\ Tn/Ac/Yr)(0.86\ Ac)}{2.47\ Ac + 0.86\ Ac}$$

$= 0.77$ Tons/Acre/yr. < 2 Tons/Acre/yr.

OK

By: M. McVey	Date: 8/19/99	Title: Potential Soil Loss from the MWL Cover by Overland Runoff
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Case 2: Vegetation is established over cover and sideslopes 12 months after seeding; 1/2 straw mulch remains.

From Table 4 (Sheet 15)

$\Rightarrow$ VM = 0.01

For 2% Cover Slope

A = 4.31 (0.01) = 0.04 Tons/Acre/yr.

For 16.7% Sideslopes

A = 20.33 (0.01) = 0.2 Tons/Acre/yr.

$$\text{Total Soil Loss} = \frac{(0.04\ \text{Tn/Ac/yr.})(2.47\ \text{Ac}) + (0.2\ \text{Tn/Ac/yr.})(0.86\ \text{Ac})}{2.47\ \text{Ac} + 0.86\ \text{Ac}}$$

= 0.08 Tons/Acre/yr. < 2 Tons/Acre/yr.

OK

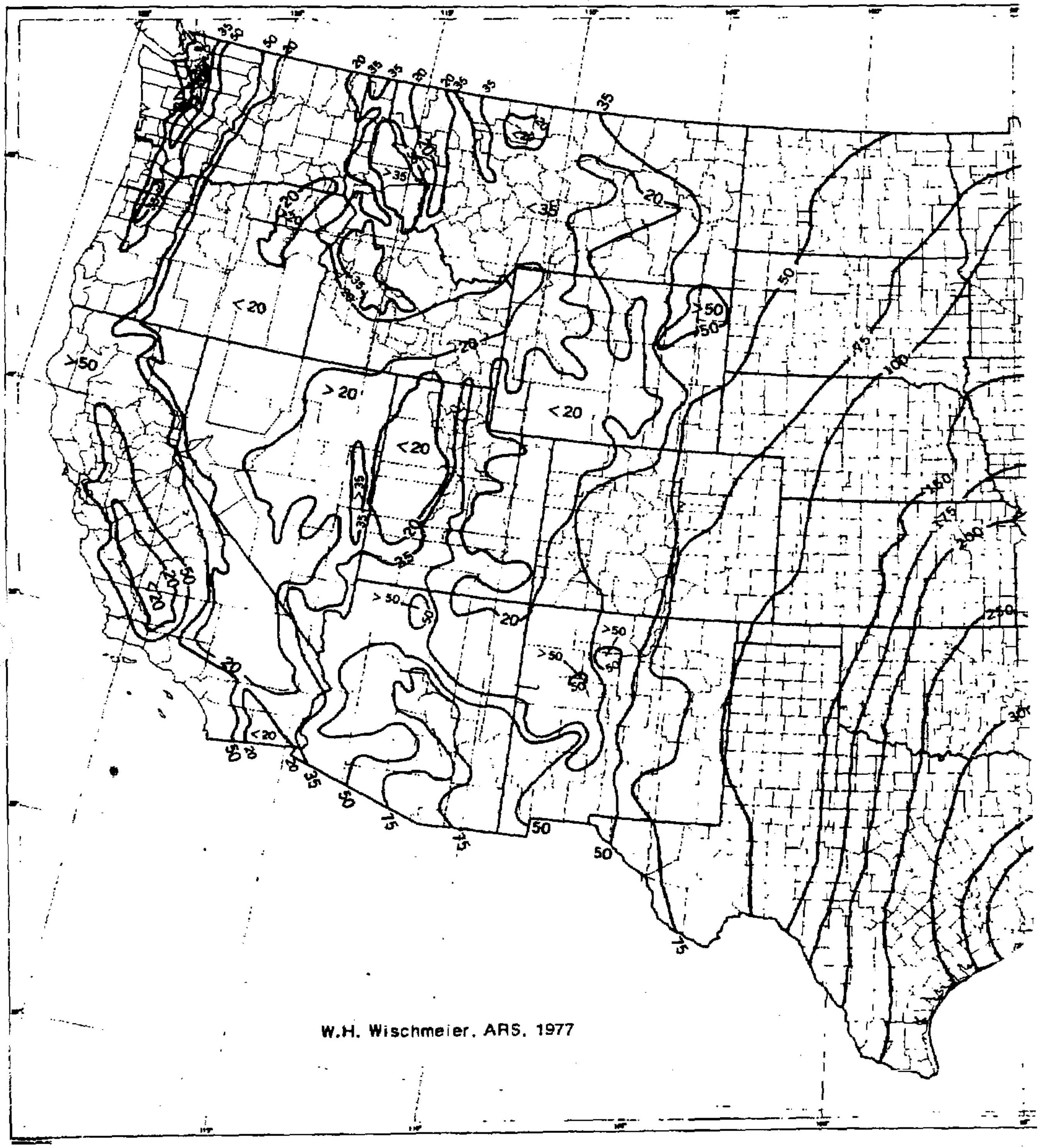

Figure 1 —Iso-erodent map illustrating average annual values of the rainfall factor, R.

Table 1.

TABULATION OF TEST RESULTS

JOB NO. 9-519-001154

DATE: 05/17/99

PROJECT: Mixed Waste Landfill Cover

SOURCE: SNI

LOCATION	DEPTH (ft.)	UNIFIED CLASS	LL	PI	SIEVE ANALYSIS - ACCUM. % PASSING 200	170	100	80	70	40	10	4	3/8	1/2	3/4	MOIST.	LAB NO.
Composite MWL-A1	0'-2'	ML	NV	NP	58	64	82	85	87	89	95	98	99	100		4.5	4557
Composite MWL-1B	2'	SM	NV	NP	25	35	56	73	79	87	95	99	100			4.3	4560
Native Soil	1 of 3	SM	NV	NP	24	35	68	74	78	83	90	94	97	100		4.8	4565
Native Soil	2 of 3	SM-SC	22	6	31	42	70	75	70	84	91	96	98	100		6.2	4566
Native Soil	3 of 3	SM	NV	NP	28	38	60	66	70	77	87	92	97	100		6.5	4567
Subgrade Soil	1 of 3	SM	NV	NP	29	40	69	75	78	82	91	96	99	100		8.4	4568
Subgrade Soil	2 of 3	SM	NV	NP	25	36	67	73	76	81	91	96	99	100		6.6	4569
Subgrade Soil	3 of 3	SM	NV	NP	27	38	69	75	78	83	91	95	100			7.3	4570
P2A	0.6'	SM	NV	NP	43	43	73	82	88	96	99	100				13.1	4571
P2A	1.5'	SM	NV	NP	28	36	63	73	81	92	96	99	100			7.1	4572
P2A	1.7'	SM	NV	NP	25	33	61	72	82	94	98	100				7.3	4573
P2D	0.6'	SM-SC	23	7	37	45	70	80	85	97	100					12.0	4574
P2E	1.0'	ML	NV	NP	62	67	83	88	92	97	99	100				5.9	4575

SM => Silty Sand (USCS)
Loamy Very Fine Sand (USDA)

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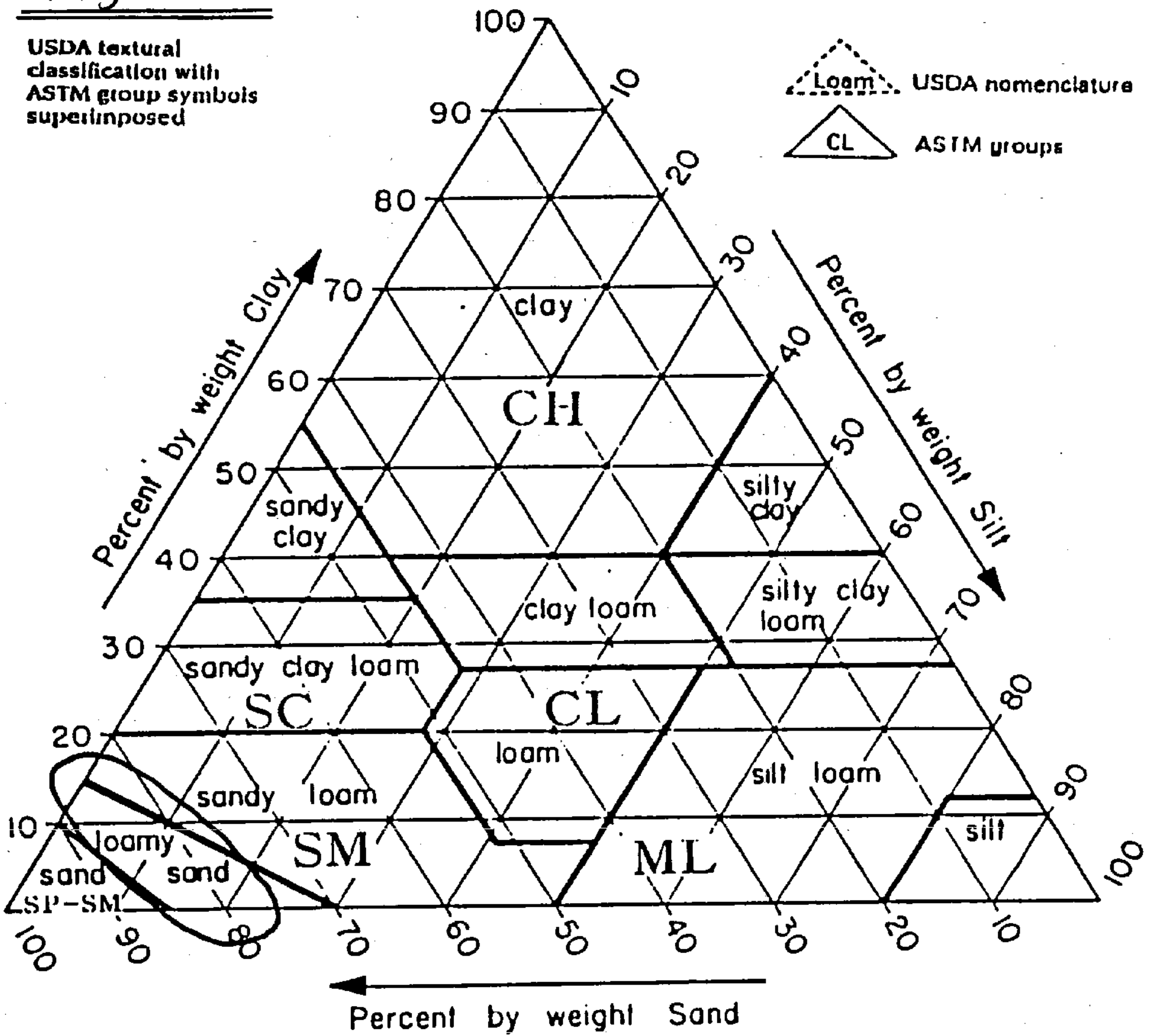
Table 2.6
Soil symbols used in USDA

USDA soil type or state	USDA symbol
Gravel	G
Sand	S
Silt	Si
Clay	C
Loam (sand, silt, clay, and humus mixture)	L
Coarse	Co
Fine	F

Figure 2.

USDA textural classification with ASTM group symbols superimposed



Sheet 12 of 15

Example 12.3

A landfill in south New Jersey is designed to have a cover with a slope of 5% of a top plateau extending from a central ridge (high point) for a distance of 300 ft. Beyond this distance, the cover slopes down to the toe at a grade of $1V$ on $4H$. The upper cover component is loamy sand with 2% organic content. Grass is the only means of erosion control. Determine the expected soil loss from sheet flow.

Solution: From Figure 12.7, $R = 200$. From Table 12.9, $K = 0.1$. From Eq. 12.21:

LS (top plateau), $m = 0.4$

$LS = (300/72.6)^{0.4}(65 \times 25 + 450 \times 5 + 650)/(25 + 10{,}000) = 0.794$

LS (side slope), $m = 0.6$

$LS = (500/72.6)^{0.6}(65 \times 625 + 450 \times 25 + 650)/(625 + 10{,}000) = 15.73$

To determine the soil loss, we begin by using Eq. 12.20 for the top plateau:

$$A = 200(0.1)(0.79)(VM) = 15.8(VM)$$

From Table 12.8, the VM factors are 0.4, for grass seedings less than 2 months old, 0.05 for those 2 to 12 months old, and 0.01 for those over 12

Table 2.

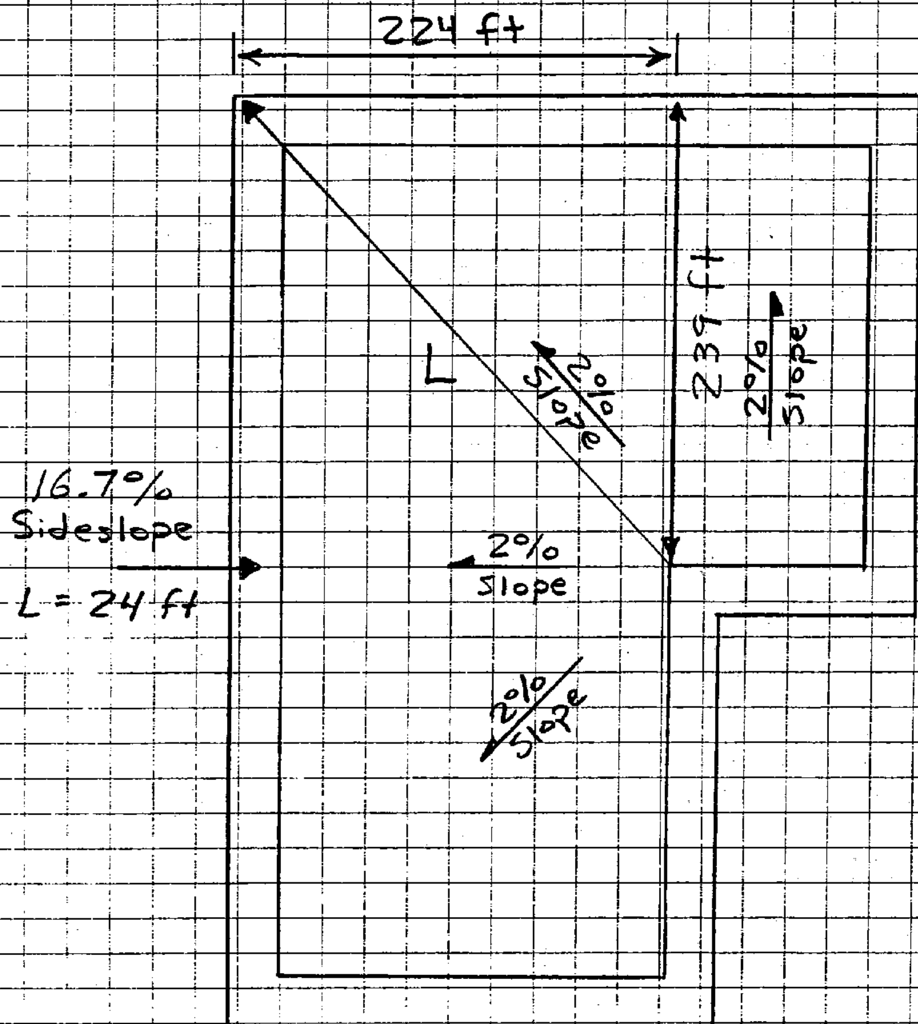
Approximate values of factor K for USDA textural classification

	Organic Matter Content		
Texture class	<0.5% K	2% K	4% K
Sand	0.05	0.03	0.02
Fine sand	0.16	0.14	0.10
Very fine sand	0.42	0.36	0.28
Loamy sand	0.12	0.10	0.08
Loamy fine sand	0.24	0.20	0.16
Loamy very fine sand	0.44	0.38	0.30
Sandy loam	0.27	0.24	0.19
Fine sandy loam	0.35	0.30	0.24
Very fine sandy loam	0.47	0.41	0.33
Loam	0.38	0.34	0.29
Silt loam	0.48	0.42	0.33
Silt	0.60	0.52	0.42
Sandy clay loam	0.27	0.25	0.21
Clay loam	0.28	0.25	0.21
Silty clay loam	0.37	0.32	0.26
Sandy clay	0.14	0.13	0.12
Silty clay	0.25	0.23	0.19
Clay		0.13–0.29	

The values shown are estimated averages of broad ranges of specific-soil values. When a texture is near the borderline of two texture classes, use the average of the two K values.

Source: Lutten et al., 1979

By: M. McVey	Date: 8/19/99	Title: Potential Soil Loss from the MWL Cover by Overland Runoff
Chkd. By: J. Peace	Date: 8/20/99	



For 2% Cover Slope

L = 327 ft

For 16.7% Sideslopes

L = 24 ft

Straw or hay mulches applied to steep construction slopes and not tied to the soil by anchoring and tacking equipment may be less effective than equivalent mulch rates on cropland. In Indiana, tests on a 20% slope of scalped subsoil, a 2.3-t rate of unanchored straw mulch allowed soil losses of 12 t/A when 5 in. of simulated rain was applied at 2.5 in./hr on a 35-ft plot (Wischmeier and Meyer, 1973). There was evidence of erosion from flow beneath the straw. Mulches of crushed stone at 135 or more t/A, or wood chips at 7 or more t/A, were more effective.

Table IV presents approximate C values for straw, crushed stone, and woodchip mulches on construction slopes where no canopy cover exists, and also shows the maximum slope lengths on which these values may be assumed to be applicable.

Soil loss ratios for many conditions on SLB, construction, and developmental areas can be obtained from Table IV if good judgment is exercised in comparing the surface conditions with those of specified agricultural conditions. Time intervals analogous to cropstage periods will be defined to begin and end with successive construction or management activities that appreciably change the surface conditions.

The observed soil loss ratios for given conditions often varied substantially from year to year because of influence of unpredictable random variables and experimental error. The percentages listed for Table V are the best available averages for a wide variety of specified agricultural conditions, only a few of which might be applicable to SLB systems. To make the table inclusive enough for general field use, expected ratios had to be computed for cover, residue, and management combinations that were not directly represented in the plot data. This was done by using empirical relationships of soil losses to the subfactors and interactions discussed in the preceding subsection. The user should recognize that the tabulated percentages are subject to appreciable experimental error and could be improved through additional research. However, because of the large volume of data considered in developing the table, the listed values should be near enough to the true averages to provide highly valuable planning and monitoring guidelines. A ratio derived locally from 1-year rainfall simulator tests on a few plots would not necessarily more accurately represent the true average for that locality. Small samples are more subject to bias by random variables and experimental error than are larger samples.

Table 3.

MULCH FACTORS AND LENGTH LIMIT FOR CONSTRUCTION SLOPES[a]

Type of Mulch	Mulch Rate (Tons/Acre)	Land Slope (%)	Factor C	La Li (
None	0	all	1.0	
Straw or hay,	1.0	1-5	0.20	2
tied down by	1.0	6-10	0.20	1
anchoring and				
tacking	1.5	1-5	0.12	3
equipment[c]	1.5	6-10	0.12	1
2% Cover Slope	$\boxed{2.0}$	$\boxed{1-5}$	$\boxed{0.06}$	4
	2.0	6-10	0.06	2
	2.0	11-15	0.07	1
16.7% Sideslopes	$\boxed{2.0}$	$\boxed{16-20}$	$\boxed{0.11}$	1
	2.0	21-25	0.14	
	2.0	26-33	0.17	
	2.0	34-50	0.20	
Crushed stone, ¾ to 1½ in	135	<16	0.05	2
	135	16-20	0.05	[illegible]
	135	21-33	0.05	
	135	34-50	0.06	
	240	<21	0.02	3
	240	21-33	0.02	2
	240	34-50	0.02	1
Wood chips	7	<16	0.08	
	7	16-20	0.08	
	12	<16	0.05	1
	12	16-20	0.05	1
	12	21-33	0.05	[illegible]
	25	<16	0.02	2
	25	16-20	0.02	1
	25	21-33	0.02	1
	25	34-50	0.02	[illegible]

[a]From Meyer and Ports (1976). Developed by an int agency workshop group on the basis of field experience a limited research data.

[b]Maximum slope length for which the specified mulch r is considered effective. When this limit is exceeded, eithe higher application rate or mechanical shortening of t effective slope length is required.

[c]When the straw or hay mulch is not anchored to the soil, values on moderate or steep slopes of soils having K valu greater than 0.30 should be taken at double the values giv in this table.

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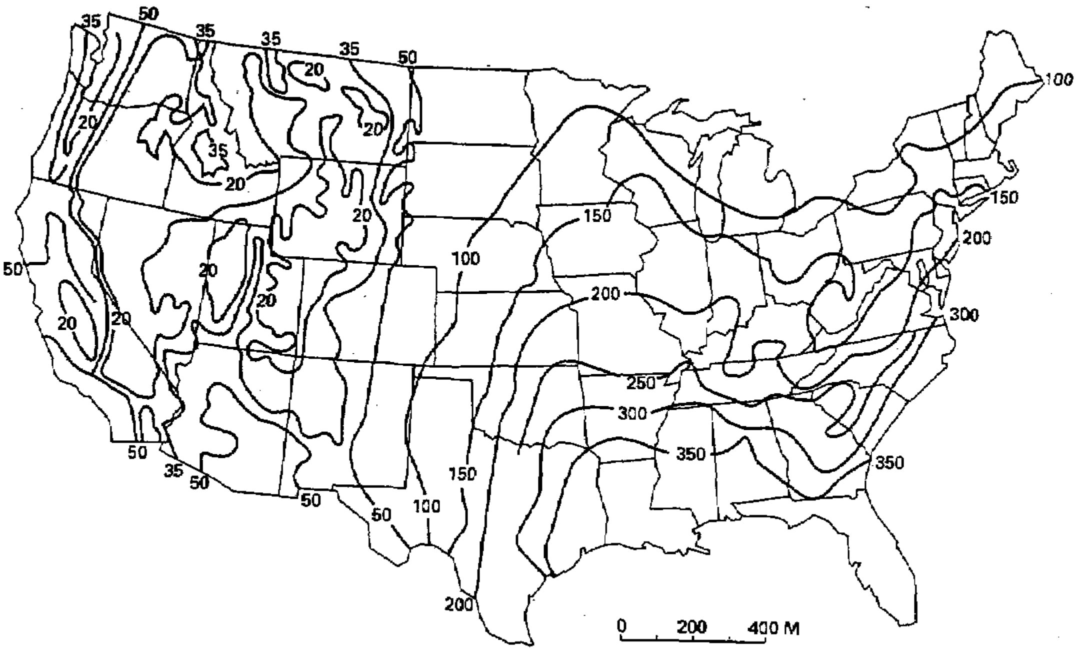

Figure 12.7 Average annual rainfall—erosivity factor R

Table 4.

Typical VM factor values

Condition	VM factor
Bare soil condition	
Freshly disked, 6–8 in.	1.0
After one rain	0.89
Loose, 12 in. thick	
Smooth	0.9
Rough	0.8
Compacted bulldozer scraped up and down	1.3
Same except roots raked	1.2
Compacted bulldozer scraped across slope	1.2
Rough irregular tracked in all directions	0.9
Seed and fertilize fresh	0.9
Same after 6 months	0.54
Compacted fill	1.24–1.71
Saw dust, 2 in. deep disked in	0.61
Dust binder	
605 gal/acre	1.05
1210 gal/acre	0.29–0.78
Hydromulch (wood fiber slurry), fresh	
1000 lb/acre	0.05
1400 lb/acre	0.01–0.02
Seedings	
Temporary, 0–60 days	0.4
After 60 days	0.05
Permanent, 0–60 days	0.4
2–12 months	0.05
After 12 months	0.01
Excelsior blanket with plastic net	0.04–0.1

Attachment 2

Potential Soil Loss

From the MWL Cover

By Wind Erosion

By: M. McVey	Date: 8/24/99	Title: Potential Soil Loss from the MWL Cover by Wind Erosion
Chkd. By: J. Peace	Date: 8/25/99	

Purpose:

Determine the soil loss due to wind erosion for the Mixed Waste Landfill alternative cover. The soil loss will be calculated by the Wind Erosion Equation (WEQ). This calculation only presents potential loss.

References:

Natural Resources Conservation Service (NRCS) National Agronomy Manual, 190-V-NAM, 2nd Ed., Part 502, March 1988.

N.P. Woodruff and F.H. Siddaway, 1965. "A Wind Erosion Equation," Soil Science Society of America Proceedings, Vol. 29, No. 5, pages 602-608.

Method of Analysis:

Standard engineering hand calculations using the Wind Erosion Equation (WEQ).

$$E = f\left[(IKC)LV\right]$$

where:

E = estimated average annual soil loss (Tons/Acre/yr.)

I = soil erodibility index

K = ridge roughness factor

C = climatic factor

L = unsheltered distance

V = vegetative factor

By: M. McVey	Date: 8/24/99	Title: Potential Soil Loss from the MWL Cover by Wind Erosion
Chkd. By: J. Peace	Date: 8/25/99	

1) Determine soil erodibility index, I:

- From Tabulation of AGRA Test Results, Table 1 (Sheet 9), USCS classification is SM.
- USDA classification for SM with sand fraction > 70% is loamy sand (Sheet 10).
- Percent passing #170 sieve indicates that the sand fraction is predominantly fine to very fine.

Soil classification ⟹ Loamy very fine sand

From Table 2 (Sheet 11) for a loamy very fine sand ⟹ I = 134 Tons/Acre/yr.

For 2% Cover Slope

I = 134 Tons/Acre/yr.

- Knoll erodibility adjustment: Adjustments of the "I" factor for knolls is used where windward facing slopes are less than 500 ft long and the increase in slope gradient from the adjacent upwind landscape is 3% or greater.

Since the windward facing slopes are > 500 ft long and < 3%, no adjustment to the soil erodibility index, I, is warranted for the 2% cover slope.

I = 134 Tons/Acre/yr.

By: M. McVey	Date: 8/24/99	Title: Potential Soil Loss from the MWL Cover by Wind Erosion
Chkd. By: J. Peace	Date: 8/25/99	

For the 16.7% Sideslopes

$I = 134$ Tons/Acre/yr.

Knoll erodibility adjustment: Since the 6:1 (16.7%) sideslopes are < 500 ft long and the windward facing slopes are > 3%, the knoll erodibility adjustment is warranted.

Max slope change = 16.7% (6:1)

From Table 3 (Sheet 12):

Adjustment to I = 1.4 multiplier

Therefore: $I = 134(1.4) = 188$

$I = 188$ Tons/Acre/yr.

2) Determine the total surface roughness, K:

$K = K_{rd}$ (ridge roughness) x K_{rr} (random roughness)

K_{rd}

Because the cover is man-made, it is assumed that the cover and sideslopes will be smooth and without ridges.

From Figure 2 (Sheet 13): $K_r = 0$

Since $K_r = 0 \Longrightarrow K_{rd} = 1.0$

By: M. McVey	Date: 8/24/99	Title: Potential Soil Loss from the MWL Cover by Wind Erosion
Chkd. By: J. Peace	Date: 8/25/99	

K_{rr}

Random roughness (rr) is the nonoriented surface roughness that is sometimes referred to as cloddiness. Cloddiness is usually created by the action of tillage implements.

From Table 4 (Sheet 14):

For drill, double disk $\Rightarrow$ rr = 0.4 inches

For 2% Cover Slope

rr = 0.4 inches

I = 134

From Figure 3 (Sheet 14) $\Longrightarrow$ $K_{rr} = 1.0$

For 16.7% Sideslopes

rr = 0.4 inches

I = 188

From Figure 3 (Sheet 14) $\Longrightarrow$ $K_{rr} = 1.0$

Total Surface Roughness for the 2% Cover Slope and the 16.7% Sideslopes

$$K = K_{rd} \times K_{rr} = (1.0)(1.0)$$

$$K = 1.0$$

By: M. McVey	Date: 8/24/99	Title: Potential Soil Loss from the MWL Cover by Wind Erosion
Chkd. By: J. Peace	Date: 8/25/99	

3) Determine the climatic factor, C:

The climatic factor is an index of the relative erosivity by geographic location.

From Figure 4 (Sheet 15) ⟹ C = 120

4) Determine the unsheltered distance, L:

The unsheltered distance is the field length along the prevailing wind direction.

For 2% Cover Slope

From Figure 5 (Sheet 16) ⟹ L = 524 ft

For 16.7% Sideslopes

From Figure 6 (Sheet 17) ⟹ L = 25 ft

5) Determine the vegetative cover factor, V:

The effect of vegetative cover in the WEQ is expressed by relating the kind, amount, and orientation of vegetative material to its equivalent in pounds per acre of small grain residue in reference condition (small grain equivalent - Sge).

Case 1: No vegetation yet established, straw mulch applied to cover and sideslopes at 2 tons/acre, crimped into soil with disk.

By: M. McVey	Date: 8/24/99	Title: Potential Soil Loss from the MWL Cover by Wind Erosion
Chkd. By: J. Peace	Date: 8/25/99	

2 Tons/Acre (straw mulch) = 4,000 lbs/Acre (Small grain residue)

From Figure 7, using the flat winter wheat residue 10" long randomly distributed reference line (because straw mulch will be lying flat on landfill cover surface)

$\Longrightarrow$ V = 4,500 Sge (small grain equivalent)

Case 2: Vegetation is established over cover and sideslopes 12 months after seeding; 1/2 straw mulch remains.

1 Ton/Acre (1/2 straw mulch remains) = 2,000 lbs/Acre (Small grain residue)

From Figure 7: 2,000 lbs/Acre small grain residue

$\Longrightarrow$ V = 2,800 Sge (small grain equivalent)

12 months after seeding, 400 Sge* of native grass is established on the cover and sideslopes.

* 400 Sge is a conservative estimate from New Mexico State Agronomist, Mike Sporcic. The estimate is based upon a two year decomposition routine contained in a revised USLE equation for grain straw decomposition in contact with soil.

$\Longrightarrow$ V = 2,800 Sge + 400 Sge = 3,200 Sge

GRAM, Inc.

Calculation Sheet

By: M. McVey	**Date:** 8/24/99	**Title:** Potential Soil Loss from the MWL Cover by Wind Erosion
Chkd. By: J. Peace	**Date:** 8/25/99	

6) Determine the average annual soil loss, E:

For 2% Cover Slope

From Table 5 (Sheet 19)

for: C = 120

I = 134

K = 1.0

L = 524 ft

Case 1:

V = 4,500 Sge

$\Longrightarrow$ E = 0 Tons/Acre/yr.

Case 2:

V = 3,200 Sge

$\Longrightarrow$ E = 0 Tons/Acre/yr.

By: M. McVey	Date: 8/24/99	Title: Potential Soil Loss from the MWL Cover by Wind Erosion
Chkd. By: J. Peace	Date: 8/25/99	

For 16.7% Sideslopes

From Table 6 (Sheet 20)

for: C = 120

I = 188

K = 1.0

L = 25 ft

Case 1:

V = 4,500 Sge

$\Longrightarrow$ E = 0 Tons/Acre/yr.

Case 2:

V = 3,200 Sge

$\Longrightarrow$ E = 0 Tons/Acre/yr.

Table 1.

TABULATION OF TEST RESULTS

JOB NO. 9-519-001154

DATE: 05/17/99

PROJECT: Mixed Waste Landfill Cover

SOURCE: SNL

LOCATION	DEPTH (ft.)	UNIFIED CLASS	LL	PI	SIEVE ANALYSIS - ACCUM. % PASSING 200	170	100	80	70	40	10	4	3/8	1/2	3/4	MOIST.	LAB NO.
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Native Soil	3 of 3	SM	NV	NP	28	38	60	66	70	77	87	92	97	100		6.5	4567
Subgrade Soil	1 of 3	SM	NV	NP	29	40	69	75	78	82	91	96	99	100		8.4	4568
Subgrade Soil	2 of 3	SM	NV	NP	25	36	67	73	76	81	91	96	99	100		6.6	4569
Subgrade Soil	3 of 3	SM	NV	NP	27	38	69	75	78	83	91	95	100			7.3	4570
P2A	0.6'	SM	NV	NP	43	43	73	82	88	96	99	100				13.1	4571
P2A	1.5'	SM	NV	NP	28	36	63	73	81	92	96	99	100			7.1	4572
P2A	1.7'	SM	NV	NP	25	33	61	72	82	94	98	100				7.3	4573
P2D	0.6'	SM-SC	23	7	37	45	70	80	88	97	100					12.0	4574
P2E	1.0'	ML	NV	NP	62	67	83	88	92	97	99	100				5.9	4575

SM => Silty Sand (USCS)
Loamy Very Fine Sand (USDA)

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Table 2.6
Soil symbols used in USDA

USDA soil type or state	USDA symbol
Gravel	G
Sand	S
Silt	Si
Clay	C
Loam (sand, silt, clay, and humus mixture)	L
Coarse	Co
Fine	F

Figure 1.

USDA textural classification with ASTM group symbols superimposed

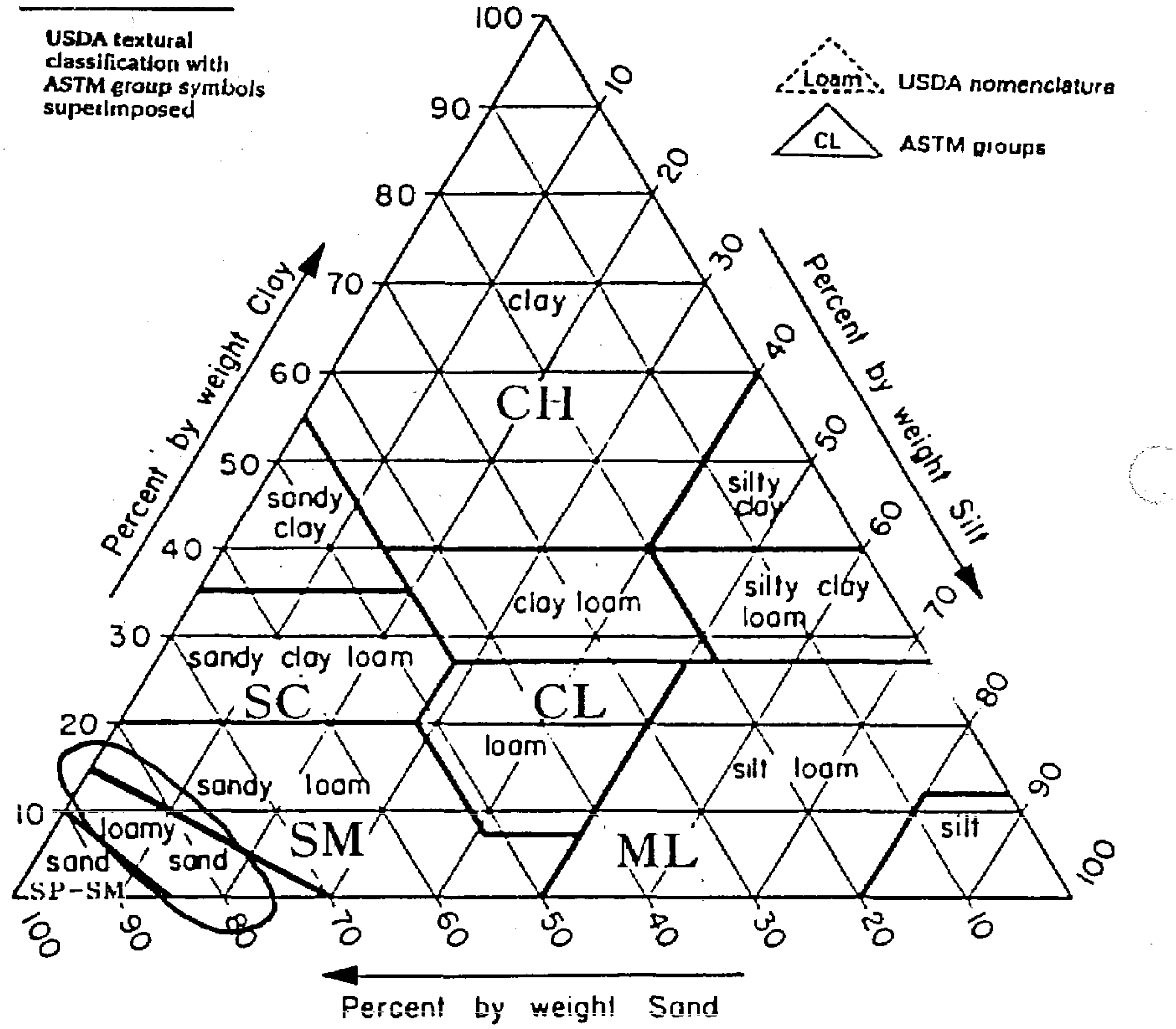


TABLE 2.

WIND ERODIBILITY GROUPS and SOIL ERODIBILITY INDEX

Predominant Soil Texture Class of Surface Layer	Wind Erodibility Group (WEG)	Soil Erodibility Index (I) (Tons/Acre/Year)[1]
Very fine sand, fine sand, sand, or coarse sand	1	310[2] 250 220 180 160
Loamy very fine sand, loamy fine sand, loamy sand, loamy coarse sand, or sapric organic soil materials	2	134
Very fine sandy loam, fine sandy loam, sandy loam, or coarse sandy loam	3	86
Clay, silty clay, noncalcareaous clay loam, or silty clay loam with more than 35 % clay	4	86
Calcareous loam and silt loam, or calcareous clay loam and silty clay loam	4L	86
Noncalcareous loam and silt loam with less than 20% clay, or sandy clay loam, sandy clay, and hemic organic soil materials	5	56
Noncalcareous loam and silt loam with more than 20% clay, or non-calcareous clay loam with less than 35% clay	6	48
Silt, non-calcareous silty clay loam with less than 35% clay, and fibric organic soil material	7	38
Soils not susceptible to wind erosion due to coarse surface fragments or wetness	8	---

[1] The soil erodibility index is based on the relationship of dry soil aggregates greater then .84 mm to potential soil erosion.

[2] The "I" factors for WEG 1 vary from 160 for coarse sands to 310 for very fine sands. Use an I of 220 as an average figure. For coarse sand with gravel, use a low figure. For no gravel and very fine sand, use a higher figure.

TABLE 3. KNOLL ERODIBILITY ADJUSTMENT FACTOR FOR I

Slope Change in Prevailing Wind Erosion Direction	A Knoll Adjustment to I	B Increase at Crest Area Where Erosion Is Most Severe
3	1.3	1.5
4	1.6	1.9
5	1.9	2.5
6	2.3	3.2
8	3.0	4.8
10	3.6	6.8
10 - 15*	2.0	–
16.7% * 15 - 20	1.4	–
20 +	1.0	–

*Factors above 10% slope change based on NRCS judgment. No research data available.

To adjust the "I" factor for knoll erodibility the "I" factor for the soil on the windward facing part of the knoll is multiplied by the factor shown in Column A of Table 3. Column B in the same table shows the increased erodibility near the crest (upper 1/3 of the slope), where the effect is most severe. This adjustment applies only to that portion of the knoll exposed to the prevailing wind erosion direction.

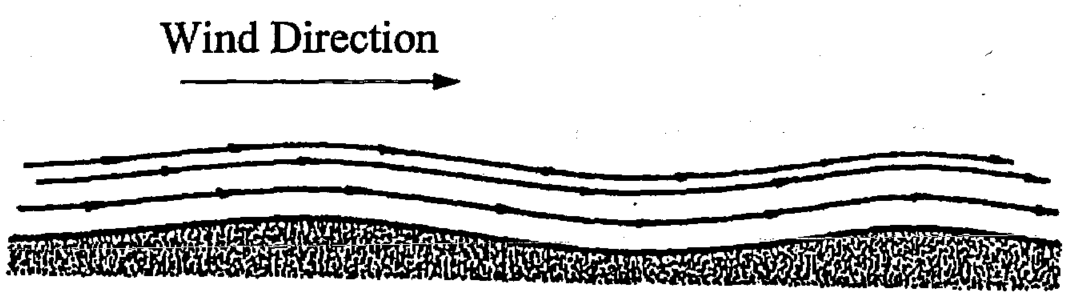
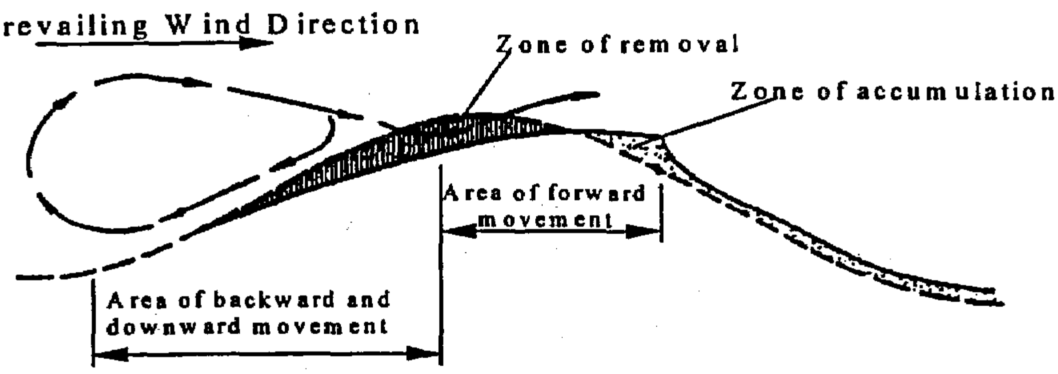


Figure 4. Wind Flow Pattern over Level to Rolling Terrain

On level fields or on rolling terrain where slopes are longer and slope changes are less than those used to describe a knoll, the wind flow pattern tends to conform to the surface and do not exhibit the flow constriction typical of knolls, as illustrated in Figure 4.



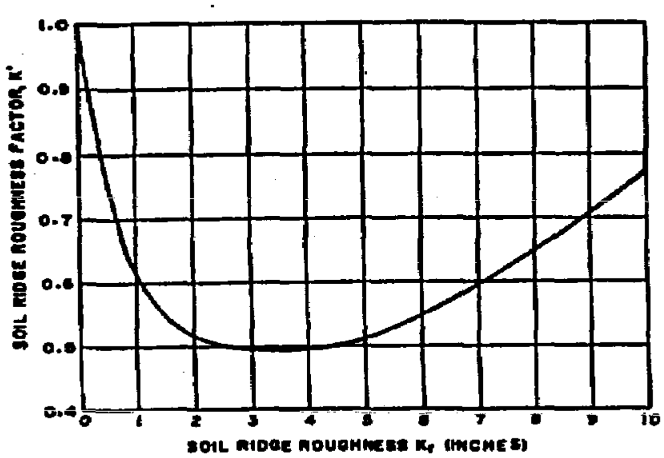
Soil Movement on Ridges

Information Needed to Determine the "K" Factor for Ridge Roughness

- Angle of Deviation
  - Prevailing wind erosion direction
  - Ridge-furrow direction
- Ridge Height
- Ridge Spacing

The "K" factor is based on a standard ridge height to ridge spacing ratio of 1:4. Calibrations of wind tunnel studies led to the development of this curve that relates ridge-furrow roughness to the "K" factor.

This curve is the basis for the "K" factor tables found in Exhibit 502.62 in the National Agronomy Manual and in the Field Office Technical Guide.



$$K_r = \frac{4h^2}{s}$$

Kral

where:
h = ridge height in inches
s = ridge spacing (inches) measured in the wind erosion direction

Figure 2. Graph to determine soil ridge roughness factor K from soil ridge roughness Kr.

Table 4. Random Roughness Values for "Core" Field Operations[1]

Field Operations	Random Roughness (in)	Field Operations	Random Roughness (in)
Chisel, sweeps	1.2[2]	Fertilizer applicator, anhydrous knife	0.6
Chisel, straight points	1.5	Harrow, spike	0.4
Chisel, twisted shovels	1.9	Harrow, tine	0.4
Cultivator, field	0.7	Lister	0.8
Cultivator, row	0.7	Manure injector	1.5
Cultivator, ridge till	0.7	Moldboard plow	1.9
Disk, one way	1.2	Mulch treader	0.4
Disk, heavy plowing	1.9	Planter, no-till	0.4
Disk, tandem	0.8	Planter, row	0.4
– Drill, double disk	0.4	Rodweeder	0.4
Drill, deep furrow	0.5	Rotary hoe	0.4
Drill, no-till	0.4	Vee ripper	1.2
Drill, no-till into sod	0.3		

[1] These values are typical and representative for operations in medium textured soils tilled at optimum moisture conditions. Many of the machines may vary by cropping region, farming practice, soil texture, or other conditions.

[2] These values may be used in WEQ for random roughness. However, the use of the random roughness photos in Agriculture Handbook 703 is preferable.

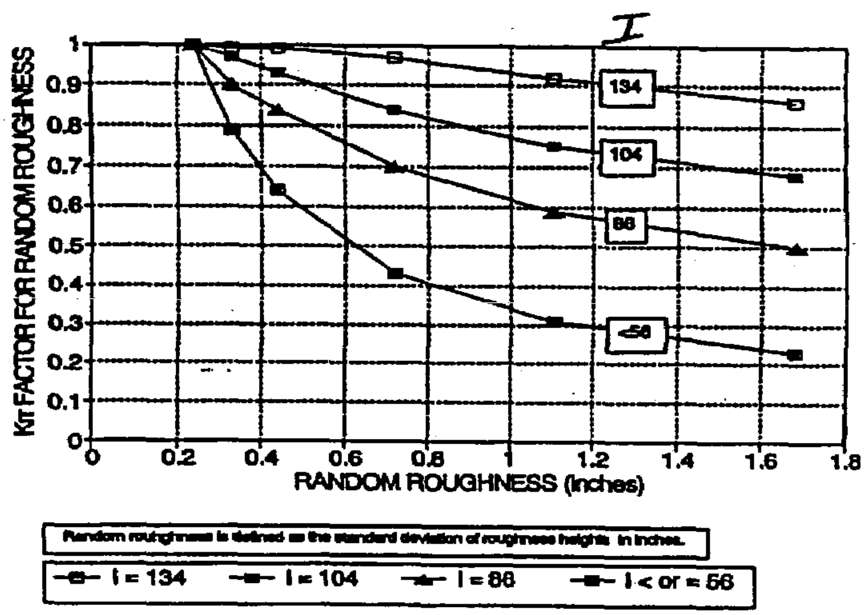


Figure 3. Graph to Determine K_{rr} from Random Roughness and "I" Factor Values

Annual "C" Values
Of The Wind Erosion Equation
New Mexico

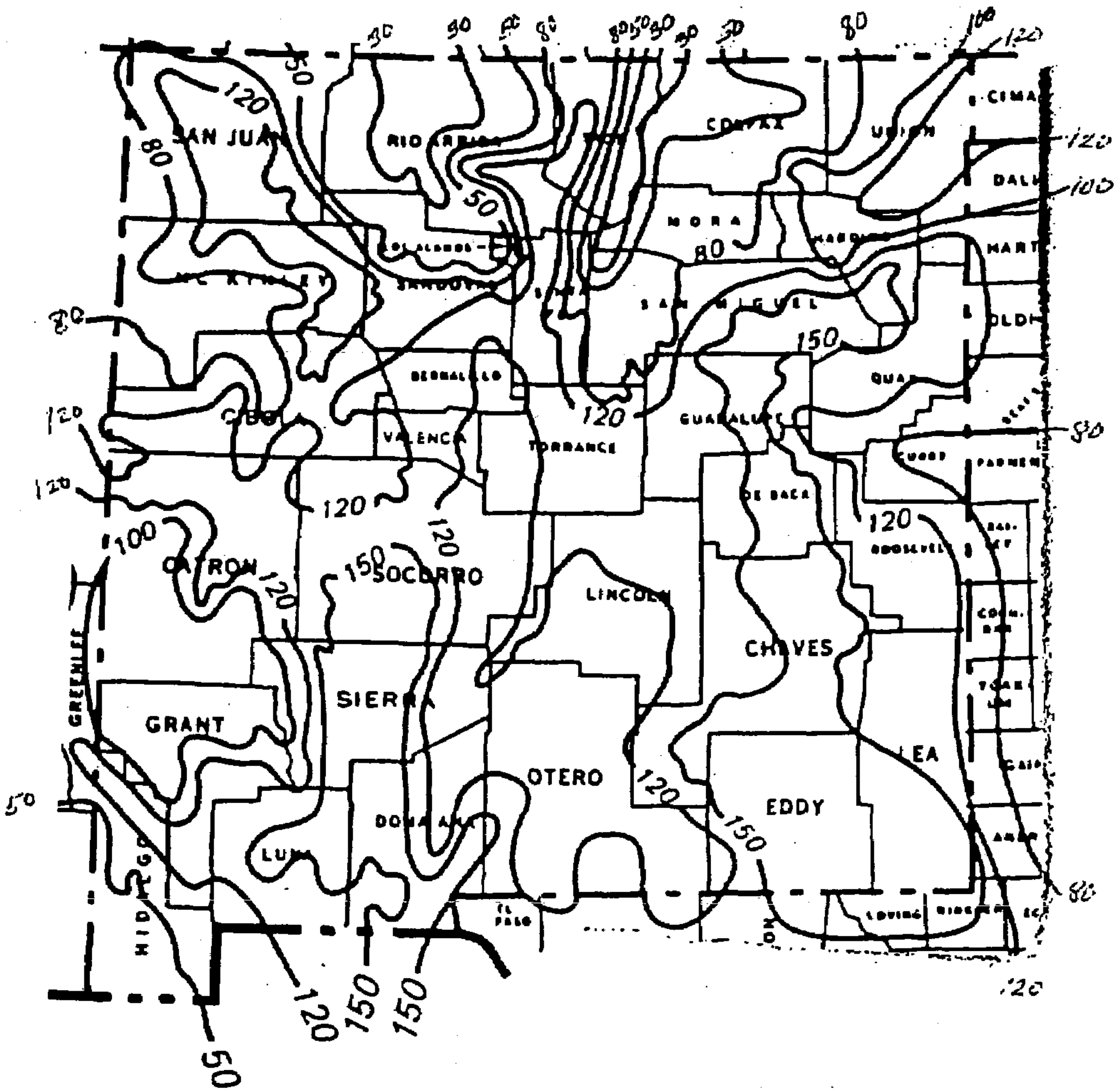


Figure 4.

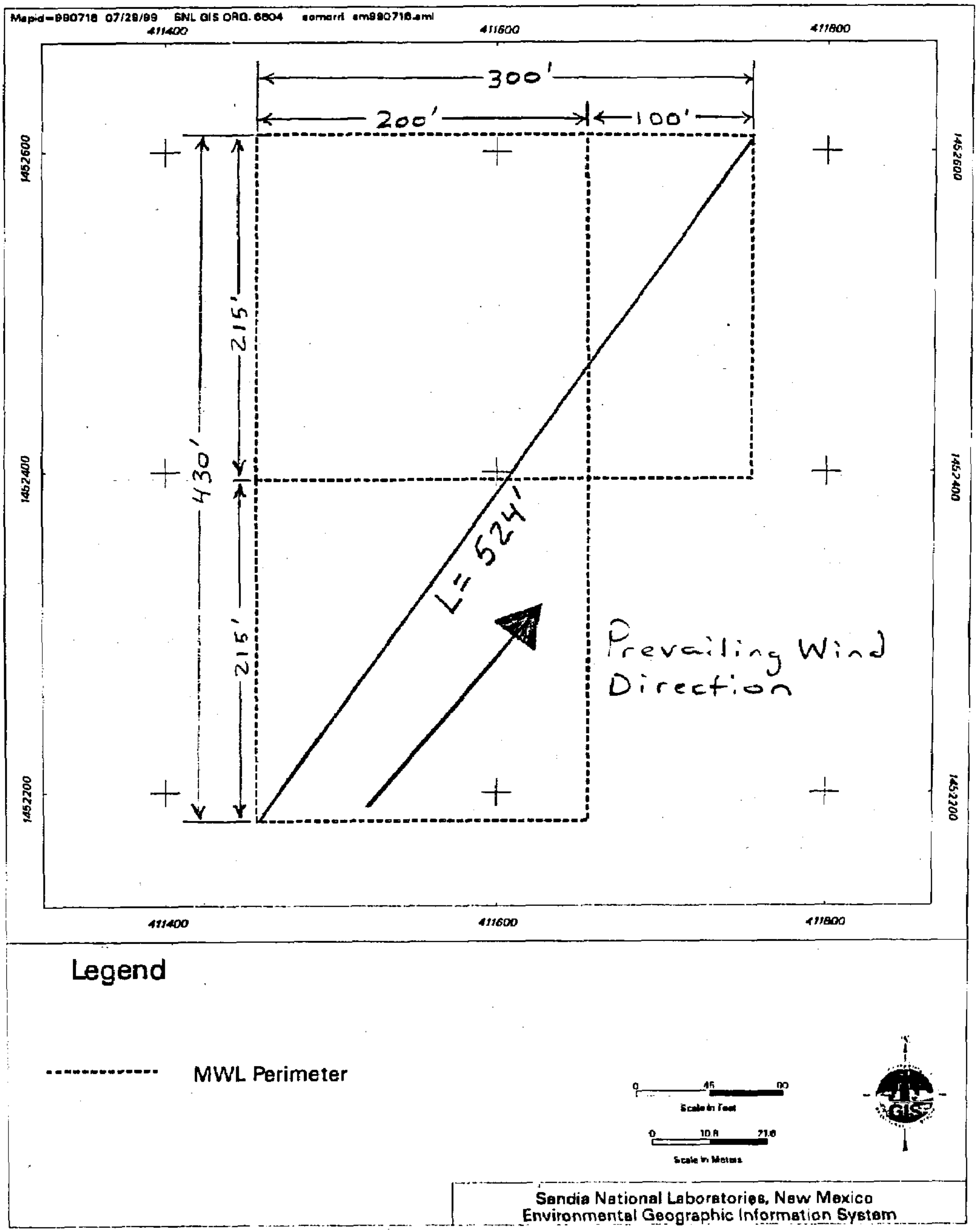


Figure 5. Unsheltered distance, L, for the 2% Cover Slope

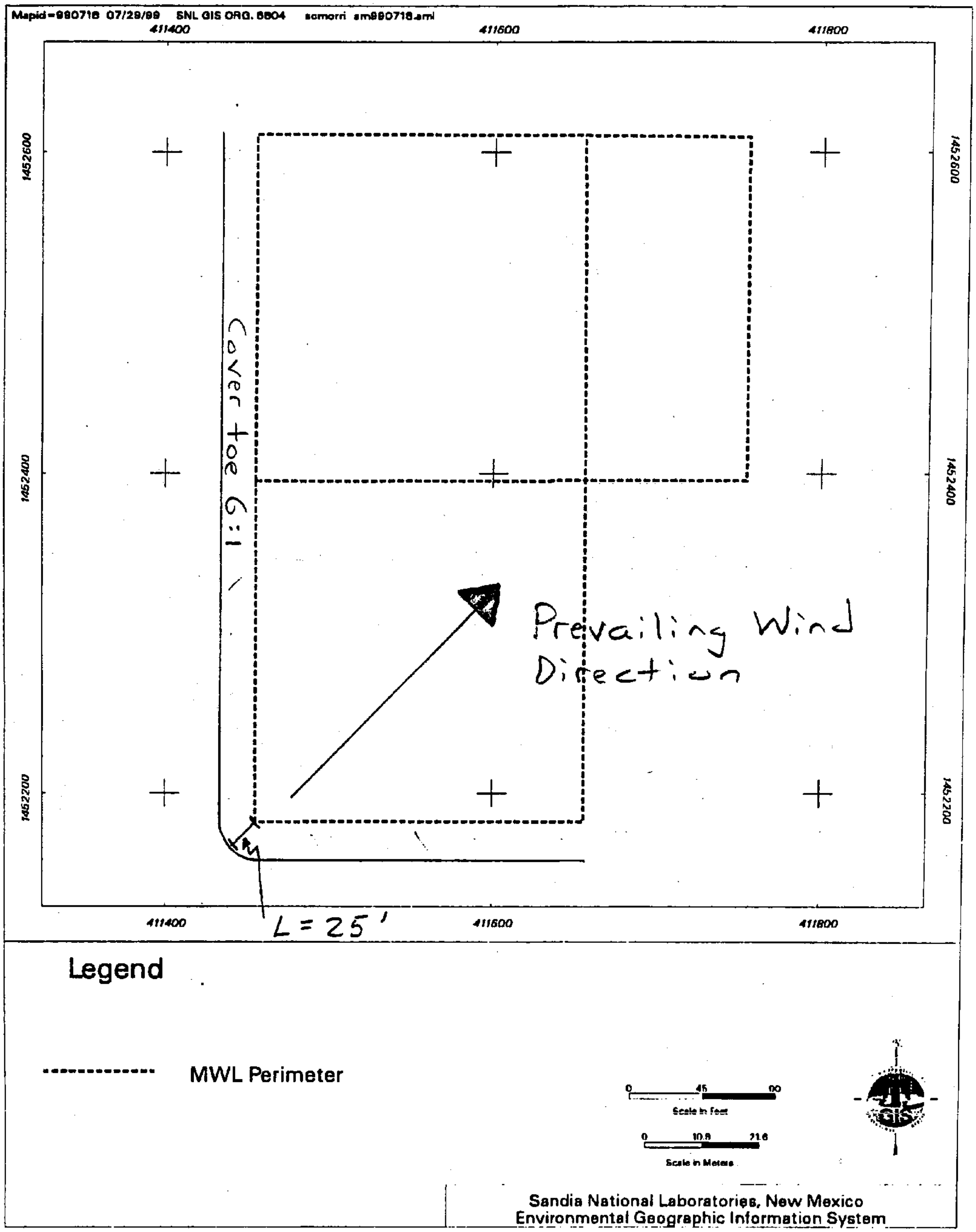


Figure 6. Unsheltered distance, L, for the 16.7% Sideslopes

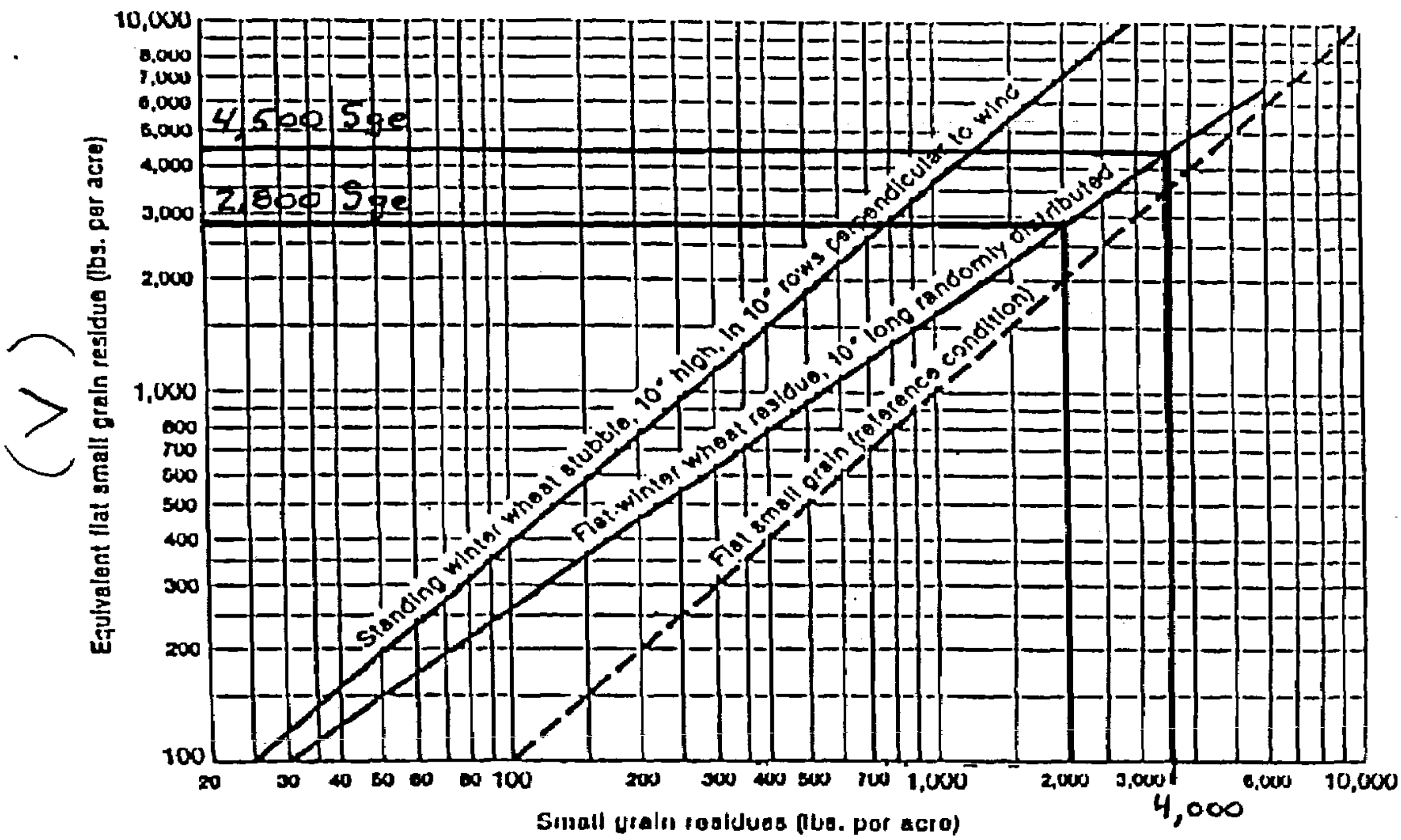
GETATIVE COVER "V"

ıd Erosion Equation E = ƒ[(IKC)LV]

getative Cover Factor "V"

: effect of vegetative cover in the Wind Erosion Equation is expressed by relating the . l, amount, and orientation of vegetative material to its equivalent in pounds per acre of ıll grain residue in reference condition (SGe).

Flat Small Grain Equivalents of Small Grain Residues
(Use for wheat, barley, rye and oats)



Reference condition - dry small grain stalks 10" long, lying flat on the soil surface in 10" rows, rows perpendicular to wind direction, stalks oriented to wind direction.
Source: Lyles and Allison—Trans. ASAE 1981, 24 (2): 405-406.
Residues are washed, air dried, and placed as described for wind tunnel tests.

Figure 7.

e Reference Condition

: term Flat Small Grain Equivalent (SGe) is based on a reference condition (dotted line ʼigure 6) developed from wind tunnel research. It is defined as:

10-inch stalks of small grain lying parallel to the wind arranged in rows

Table 5. C=120, I=134, k=1.0

WIND EROSION EQUATION "C" FACTORS

NEW MEXICO

(E)* SOIL LOSS FROM WIND EROSION IN TONS PER ACRE PER YEAR — JANUARY, 1998

C = 120
I = 134

SURFACE - K =1.00

(V)** - FLAT SMALL GRAIN RESIDUE IN POUNDS PER ACRE

(L) UNSHELTERED DISTANCE IN FEET	0	250	500	750	1000	1250	1500	1750	2000	2250	2500	2750	3000
10000	160.8	144.5	122.7	101.4	70.1	49.4	30.1	19.0	12.2	6.6	3.7	0.8	0.4
8000	160.8	144.5	122.7	101.4	70.1	49.4	30.1	19.0	12.2	6.6	3.7	0.8	0.4
6000	160.8	144.5	122.7	101.4	70.1	49.4	30.1	19.0	12.2	6.6	3.7	0.8	0.4
4000	160.8	144.5	122.7	101.4	70.1	49.4	30.1	19.0	12.2	6.6	3.7	0.8	0.4
3000	160.8	144.5	122.7	101.4	70.1	49.4	30.1	19.0	12.2	6.6	3.7	0.8	0.4
2000	160.8	144.5	122.7	101.4	70.1	49.4	30.1	19.0	12.2	6.6	3.7	0.8	0.4
1000	153.2	137.4	116.2	95.5	65.4	45.4	27.4	17.1	10.8	5.8	3.2	0.7	0.4
800	151.0	135.3	114.3	93.7	64.0	44.3	26.6	16.5	10.5	5.5	3.0	0.6	0.3
600	144.7	129.5	109.0	88.9	60.2	41.2	24.5	15.0	9.4	4.9	2.6	0.2	0.0
524' > 400	137.4	122.7	102.8	83.3	55.9	37.6	22.1	13.3	8.3	4.2	2.2	0.2	
300	131.6	117.2	97.9	78.9	52.5	34.9	20.3	12.1	7.4	3.7	1.9	0.2	
200	120.2	106.7	88.5	70.5	46.1	29.9	17.0	9.8	5.9	2.8	1.4	0.1	
150	111.5	98.7	81.3	64.2	41.4	26.3	14.6	8.3	4.9	2.3	1.1	0.1	
100	104.4	92.1	75.5	59.1	37.6	23.4	12.8	7.1	4.1	1.9	0.9	0.1	
80	98.5	86.7	70.7	54.9	34.6	21.2	11.4	6.3	3.6	1.6	0.7	0.1	
60	88.7	77.7	62.8	48.2	29.7	17.7	9.3	4.9	2.8	1.2	0.4	0.0	
50	82.8	72.4	58.2	44.2	26.9	15.7	8.1	4.2	2.3	1.0	0.3		
40	77.5	67.5	54.0	40.7	24.5	14.0	7.1	3.6	2.0	0.7	0.0		
30	69.3	60.1	47.7	35.4	20.9	11.6	5.7	2.8	1.5	0.5			
20	57.9	49.8	38.9	28.3	16.1	8.5	4.0	1.9	0.9	0.0			
10	43.2	36.8	28.1	19.7	10.6	5.1	2.3	1.0	0.3				

(E)* SOIL LOSS FROM WIND EROSION IN TONS PER ACRE PER YEAR — JANUARY, 1998

C = 120
I = 134

SURFACE - K =0.90

(V)** - FLAT SMALL GRAIN RESIDUE IN POUNDS PER ACRE

(L) UNSHELTERED DISTANCE IN FEET	0	250	500	750	1000	1250	1500	1750	2000	2250	2500	2750	3000
10000	144.7	129.5	109.0	88.9	60.2	41.2	24.5	15.0	9.1	4.9	2.6	0.2	
8000	144.7	129.5	109.0	88.9	60.2	41.2	24.5	15.0	9.4	4.9	2.6	0.2	
6000	144.7	129.5	109.0	88.9	60.2	41.2	24.5	15.0	9.4	4.9	2.6	0.2	
4000	144.7	129.5	109.0	88.9	60.2	41.2	24.5	15.0	9.4	4.9	2.6	0.2	
3000	144.7	129.5	109.0	88.9	60.2	41.2	24.5	15.0	9.4	4.9	2.6	0.2	
2000	143.2	128.0	107.6	87.7	59.3	40.4	23.9	14.6	9.1	4.7	2.5	0.2	
1000	137.3	122.6	102.7	83.3	55.8	37.6	22.1	13.3	8.2	4.2	2.2	0.2	
800	132.5	118.1	98.7	79.7	53.1	35.4	20.6	12.3	7.5	3.8	2.0	0.2	
600	126.6	112.7	93.8	75.2	49.7	32.7	18.8	11.1	6.7	3.3	1.7	0.1	
400	118.1	104.8	86.7	69.0	44.9	29.0	16.4	9.5	5.6	2.7	1.3	0.1	
300	112.0	99.1	81.7	64.5	41.6	26.4	14.8	8.4	4.9	2.3	1.1	0.1	
200	104.1	91.9	75.3	58.9	37.5	23.3	12.8	7.1	4.1	1.9	0.9	0.1	
150	96.6	85.0	69.2	53.7	33.6	20.5	11.0	6.0	3.4	1.5	0.7	0.1	
100	88.7	77.8	62.9	48.2	29.7	17.7	9.3	4.9	2.8	1.2	0.4		
80	83.1	72.6	58.4	44.4	27.1	15.8	8.2	4.3	2.3	1.0	0.3		
60	74.3	64.7	51.6	38.7	23.1	13.0	6.6	3.3	1.8	0.7			
50	69.8	60.6	48.0	35.7	21.1	11.7	5.8	2.9	1.5	0.6			
40	64.8	56.1	44.2	32.6	18.9	10.3	5.0	2.4	1.3				
30	57.2	49.3	38.4	27.9	15.8	8.3	3.9	1.8	0.9				
20	48.8	41.8	32.1	22.9	12.6	6.3	2.9	1.3	0.4				
10	35.4	29.9	22.4	15.3	8.0	3.6	1.5	0.5					

* NOTE: SOIL LOSS FOR VALUES WHERE 'E' IS LESS THAN 0.1 OR GREATER THAN 440.0 ARE NOT SHOWN; OTHER VALUES NOT SHOWN ARE INVALID

** NOTE: VALUES SHOWN ARE FLAT SMALL GRAIN EQUIVALENT, NOT 'V'

Sheet 19 of 20

Table 6. C = 120, I = 180, K = 1.0

WIND EROSION EQUATION "C" FACTORS

NEW MEXICO

(E)* SOIL LOSS FROM WIND EROSION IN TONS PER ACRE PER YEAR — JANUARY, 1998 — C = 120 — I = 180

SURFACE - K =1.00

(V)** - FLAT SMALL GRAIN RESIDUE IN POUNDS PER ACRE

(L) UNSHELTERED DISTANCE IN FEET	0	250	500	750	1000	1250	1500	1750	2000	2250	2500	2750	3000
10000	216.0	196.6	171.0	146.7	107.5	82.3	54.0	37.2	25.7	15.7	9.8	2.4	1.6
8000	216.0	196.6	171.0	146.7	107.5	82.3	54.0	37.2	25.7	15.7	9.8	2.4	1.6
6000	216.0	196.6	171.0	146.7	107.5	82.3	54.0	37.2	25.7	15.7	9.8	2.4	1.6
4000	216.0	196.6	171.0	146.7	107.5	82.3	54.0	37.2	25.7	15.7	9.8	2.4	1.6
3000	216.0	196.6	171.0	146.7	107.5	82.3	54.0	37.2	25.7	15.7	9.8	2.4	1.6
2000	216.0	196.6	171.0	146.7	107.5	82.3	54.0	37.2	25.7	15.7	9.8	2.4	1.6
1000	214.0	194.7	169.2	145.0	106.1	81.0	53.0	36.5	25.1	15.3	9.5	2.4	1.6
800	211.0	191.8	166.5	142.5	103.9	79.1	51.5	35.3	24.2	14.7	9.1	2.2	1.5
600	206.0	187.1	162.1	138.2	100.4	75.8	49.1	33.4	22.8	13.7	8.4	2.0	1.3
400	196.7	178.3	153.8	130.5	93.9	70.0	44.8	30.1	20.3	12.0	7.2	1.7	1.1
300	190.0	172.0	148.0	124.9	89.3	65.9	41.9	27.8	18.6	10.8	6.4	1.5	1.0
200	179.0	161.6	138.4	116.0	81.9	59.5	37.3	24.3	16.0	9.1	5.3	1.2	0.6
150	167.2	150.5	128.2	106.5	74.2	52.8	32.5	20.8	13.5	7.4	4.2	0.9	0.5
100	156.0	140.0	118.6	97.6	67.1	46.9	28.4	17.8	11.4	6.1	3.4	0.7	0.4
80	147.3	131.9	111.2	90.9	61.8	42.5	25.4	15.6	9.8	5.1	2.8	0.6	0.0
60	135.7	121.1	101.4	82.0	54.9	36.8	21.6	13.0	8.0	4.0	2.1	0.2	
50	127.8	113.7	94.7	76.1	50.3	33.2	19.1	11.3	6.9	3.4	1.7	0.1	
40	119.7	106.2	88.0	70.1	45.8	29.6	16.8	9.7	5.8	2.8	1.4	0.1	
25' 30	109.5	96.8	79.6	62.7	40.3	25.4	14.1	8.0	4.7	2.2	1.0	0.1	
20	94.6	83.1	67.6	52.2	32.6	19.7	10.6	5.7	3.2	1.4	0.4	0.0	
10	72.7	63.2	50.3	37.6	22.4	12.6	6.3	3.2	1.7	0.6	0.0		

(E)* SOIL LOSS FROM WIND EROSION IN TONS PER ACRE PER YEAR — JANUARY, 1998 — C = 120 — I = 180

SURFACE - K =0.90

(V)** - FLAT SMALL GRAIN RESIDUE IN POUNDS PER ACRE

(L) UNSHELTERED DISTANCE IN FEET	0	250	500	750	1000	1250	1500	1750	2000	2250	2500	2750	3000
10000	194.4	176.1	151.9	128.6	92.3	68.6	43.8	29.3	19.7	11.6	6.9	1.6	1.1
8000	194.4	176.1	151.9	128.6	92.3	68.6	43.8	29.3	19.7	11.6	6.9	1.6	1.1
6000	194.4	176.1	151.9	128.6	92.3	68.6	43.8	29.3	19.7	11.6	6.9	1.6	1.1
4000	194.4	176.1	151.9	128.6	92.3	68.6	43.8	29.3	19.7	11.6	6.9	1.6	1.1
3000	194.4	176.1	151.9	128.6	92.3	68.6	43.8	29.3	19.7	11.6	6.9	1.6	1.1
2000	194.4	176.1	151.9	128.6	92.3	68.6	43.8	29.3	19.7	11.6	6.9	1.6	1.1
1000	189.6	171.6	147.6	124.6	89.0	65.7	41.7	27.7	18.5	10.7	6.4	1.5	1.0
800	186.4	168.5	144.8	122.0	86.8	63.8	40.3	26.6	17.7	10.2	6.0	1.4	0.7
600	182.7	165.1	141.6	119.0	84.4	61.6	38.8	25.5	16.9	9.6	5.7	1.3	0.7
400	174.1	156.9	134.1	112.0	78.7	56.6	35.2	22.8	14.9	8.4	4.8	1.1	0.6
300	167.3	150.6	128.3	106.6	74.3	52.9	32.6	20.8	13.5	7.5	4.2	0.9	0.5
200	153.1	137.3	116.1	95.4	65.3	45.3	27.3	17.0	10.8	5.7	3.2	0.7	0.4
150	143.3	128.1	107.7	87.8	59.4	40.5	24.0	14.7	9.2	4.7	2.5	0.2	
100	134.1	119.6	100.0	80.8	54.0	36.1	21.1	12.6	7.8	3.9	2.0	0.2	
80	126.3	112.3	93.5	75.0	49.5	32.5	18.7	11.0	6.7	3.3	1.7	0.1	
60	114.9	101.8	84.1	66.6	43.2	27.6	15.5	8.9	5.3	2.5	1.2	0.1	
50	108.3	95.8	78.7	61.9	39.7	25.0	13.8	7.8	4.5	2.1	1.0	0.1	
40	102.8	90.7	74.2	58.0	36.8	22.8	12.5	6.9	4.0	1.8	0.9	0.1	
30	94.5	83.1	67.5	52.2	32.6	19.7	10.6	5.7	3.2	1.4	0.4		
20	79.5	69.4	55.6	42.1	25.4	14.6	7.5	3.9	2.1	0.8			
10	60.1	51.8	40.6	29.7	17.0	9.0	4.3	2.0	1.0				

* NOTE: SOIL LOSS FOR VALUES WHERE 'E' IS LESS THAN 0.1 OR GREATER THAN 440.0 ARE NOT SHOWN; OTHER VALUES NOT SHOWN ARE INVALID

** NOTE: VALUES SHOWN ARE FLAT SMALL GRAIN EQUIVALENT, NOT 'V'

Sheet 20 of 20

Attachment 3

Calculations

Regarding

Run-Off and Run-On Controls

For the MWL Cover

NMED (NOD) COMMENT: "Demonstrate with calculations and other information whether run-off and run-on controls have been adequately designed to handle peak precipitation events. Evaluate and discuss whether additional fun-on controls should be constructed at locations further away from the landfill (e.g. at distances of 25 to 50 meters) to provide more protection for the cover from heavy rainfall events."

Response to NMED (NOD) Comment;

The site will be graded such that runoff from the site flows north, west and east. There is a high point on the north side of the site that prevents flow from running onto the site. Two swales will be provided to carry the flow to the north or the south. This may be seen in Exhibit 1: Mixed Waste Landfill Final Cover Grading Plan" attached.

The watershed basin draining onto the site has been delineated and is shown on Exhibit 2. It is divided in to a north basin and a south basin that drain to the north and south swales respectively.

Runoff was calculated using the City of Albuquerque DPM criteria for the 100 year –6 hour storm. Reference: DPM Criteria Attached. The north basin generates 24 cfs and the north swale has the capacity for 79 cfs. The south basin generates 6.5 cfs and the capacity of the south swale is 58 cfs.

The swales are therefore sized with abundant capacity to prevent flow from entering the site and to carry the runoff around the site.

The general drainage pattern in this area is a gentle slope to the west. So after the flow is discharged from the site, they drain westward and no additional controls are needed. Exhibit 2 shows the topography up to a minimum of 200 feet beyond the site to illustrate this.

URS

Job: Mixed Waste Landfill Project Project No. Sheet of
Description: Response to NMED Comment No. 16, Computed by [signature] Date 11 Dec. 06
Checked by HB PE Date 11 Dec. 06
Reference

USE CITY of ALB. DRAINAGE METHOD

BASIN AREA

NORTH 297636 $\square'$

SOUTH 81997.54 $\square'$

TOTAL = 379633.54 SF ✓

Time of Concentration

longest flow path

N = 964' SLOPE sheet flow $\frac{97.2-91.7}{400} = .01375$ %

other $\frac{5391.7-5380}{564} = .02074$ %

S = 616' Slope = $\frac{5388-5382}{616} = 0.0097$ %

Zone 3

LAND TREATMENT

⇒ SAY Type C possibly some type A is there but much of the area has been impacted by human activity

this is conservative

Time of Concentration

NORTH $t_c = L_1/V_1 + L_2/V_2 \ldots$

$V = K\sqrt{S*1000}$

$V_1 = .7\sqrt{.01375(100)} = 0.82$ ✓

$V_2 = 2\sqrt{.02074(100)} = 2.88$ ✓

= 11 min

$T_c = \left(400'/0.82\,\frac{ft}{sec} + 564'/2.88\,ft/sec\right) / (3600\ sec/hour) = 0.1899$ hrs

URS

Job Mixed Waste Landfill Project Project No.

Sheet of

Description Response to NMED Comment No. 16. Computed by SJ Date 11 Dec. 06

Checked by HB CE Date 11 Dec. 06

Reference

SOUTH use $K = 2$

$$V = 2\sqrt{.0097(100)} = 1.97$$

$$T_c = \frac{616 \text{ ft}}{1.97 \frac{\text{ft}}{\text{sec}}} = 312.7 \text{ sec} = 5 \text{ min}$$

NORTH + SOUTH - Both < 12 min

Use TABLE A-9 for Qpeak-100

Zone 3 / L.T. C

NORTH 297636 ft² = 6.833 Ac

SOUTH 81997.54 ft² = 1.882 Ac

$$Q_{peak} \text{ NORTH} = 6.833 \text{Ac} \left(3.45 \frac{\text{cfs}}{\text{Acre}}\right) = 23.6 \text{cfs}$$

$$Q_{peak} \text{ SOUTH} = 1.882 \text{Ac} \left(3.45 \frac{\text{cfs}}{\text{Ac}}\right) = 6.5 \text{cfs}$$

NORTH SWALE - Q100

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Channel Slope	0.02000	ft/ft
Discharge	23.60	ft³/s

Section Definitions

Station (ft)	Elevation (ft)
1+00	5388.00
1+40	5382.00
1+56	5381.00
1+86	5382.50

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(1+00, 5388.00)	(1+86, 5382.50)	0.030

Results

Normal Depth	0.63	ft
Elevation Range	5381.00 to 5388.00 ft	
Flow Area	7.25	ft²
Wetted Perimeter	22.88	ft
Top Width	22.84	ft
Normal Depth	0.63	ft
Critical Depth	0.64	ft
Critical Slope	0.01922	ft/ft
Velocity	3.26	ft/s
Velocity Head	0.16	ft
Specific Energy	0.80	ft
Froude Number	1.02	
Flow Type	Supercritical	

NORTH SWALE - Q100

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	0.63	ft
Critical Depth	0.64	ft
Channel Slope	0.02000	ft/ft
Critical Slope	0.01922	ft/ft

NORTH SWALE - CAPACITY

Project Description

Friction Method	Manning Formula
Solve For	Discharge

Input Data

Channel Slope	0.02000	ft/ft
Normal Depth	1.00	ft

Section Definitions

Station (ft)	Elevation (ft)
1+00	5388.00
1+40	5382.00
1+56	5381.00
1+86	5382.50

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(1+00, 5388.00)	(1+86, 5382.50)	0.030

Results

Discharge	79.35	ft^3/s
Elevation Range	5381.00 to 5388.00 ft	
Flow Area	18.00	ft^2
Wetted Perimeter	36.06	ft
Top Width	36.00	ft
Normal Depth	1.00	ft
Critical Depth	1.04	ft
Critical Slope	0.01631	ft/ft
Velocity	4.41	ft/s
Velocity Head	0.30	ft
Specific Energy	1.30	ft
Froude Number	1.10	
Flow Type	Supercritical	

NORTH SWALE - CAPACITY

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	1.00	ft
Critical Depth	1.04	ft
Channel Slope	0.02000	ft/ft
Critical Slope	0.01631	ft/ft

SOUTH SWALE - CAPACITY

Project Description

Friction Method	Manning Formula
Solve For	Discharge

Input Data

Channel Slope	0.00900	ft/ft
Normal Depth	1.10	ft

Section Definitions

Station (ft)	Elevation (ft)
1+00	5388.00
1+24	5384.00
1+32	5383.90
1+39	5385.00

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(1+00, 5388.00)	(1+39, 5385.00)	0.030

Results

Discharge	57.58	ft^3/s
Elevation Range	5383.90 to 5388.00 ft	
Flow Area	15.25	ft^2
Wetted Perimeter	21.17	ft
Top Width	21.00	ft
Normal Depth	1.10	ft
Critical Depth	0.97	ft
Critical Slope	0.01529	ft/ft
Velocity	3.78	ft/s
Velocity Head	0.22	ft
Specific Energy	1.32	ft
Froude Number	0.78	
Flow Type	Subcritical	

SOUTH SWALE - CAPACITY

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	1.10	ft
Critical Depth	0.97	ft
Channel Slope	0.00900	ft/ft
Critical Slope	0.01529	ft/ft

SOUTH SWALE - Q100

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Channel Slope	0.00900	ft/ft
Discharge	6.50	ft³/s

Section Definitions

Station (ft)	Elevation (ft)
1+00	5388.00
1+24	5384.00
1+32	5383.90
1+39	5385.00

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(1+00, 5388.00)	(1+39, 5385.00)	0.030

Results

Normal Depth		0.38	ft
Elevation Range	5383.90 to 5388.00 ft		
Flow Area		3.29	ft²
Wetted Perimeter		12.11	ft
Top Width		12.05	ft
Normal Depth		0.38	ft
Critical Depth		0.30	ft
Critical Slope		0.02186	ft/ft
Velocity		1.97	ft/s
Velocity Head		0.06	ft
Specific Energy		0.44	ft
Froude Number		0.67	
Flow Type	Subcritical		

SOUTH SWALE - Q100

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	0.38	ft
Critical Depth	0.30	ft
Channel Slope	0.00900	ft/ft
Critical Slope	0.02186	ft/ft

TABLE 22.3 B-1

VALUES OF MANNING'S n

	n
Reinforced Concrete Pipe	.013
Poured Concrete	.013
No-joint cast in place concrete pipe	.014
Reinforced Concrete Box	.015
Reinforced Concrete Arch	.015
Streets	.017
Flush Grouted Rip-Rap	.020
Corrugated Metal Pipe	.025
Grass Lined Channels (sodded & irrigated)	.025
Earth Lined Channels (smooth)	.030
Arroyo Channels	.030
Wire Tied Rip-Rap	.040
Medium Weight Dumped Riprap	.045
Grouted Rip-Rap (exposed rock)	.045
Arroyo Overbank	.045
Jetty Type Rip-Rap (D_{50} > 24")	.050

Following incorporation of review comments, the August, 1991 version of Section 22.2, Hydrology was released for use by the Drainage Design Criteria Committee. This version included the placement of the rainfall peak in this second hour of the design storm. Modifications to the Probable Maximum Flood procedures incorporated a "local storm" and a "general storm." A "Notice of Second Review" was published in the Albuquerque Journal and Tribune on August 31, 1991. The August, 1991 version has been accepted by the City, County and AMAFCA as an allowable procedure for hydrologic analysis and design of flood control structures.

The January, 1993 version of Section 22.2, Hydrology incorporates comments received since August, 1991. The version includes a procedure to evaluate basin hydrology for steep natural slopes, and some text revisions suggested by the USDA Soil Conservation Service. For most applications, there will be no computational differences between the January, 1993 version and the August, 1991 version. The text has been reformatted into seven (7) separately numbered parts, to simplify future revision of the document.

The pages which follow replaced all previous pages in the Hydrology Section of the DPM (Section 22.2, pages 2 through 21). Following a public review and comment period, the revised Section 22.2, Hydrology was approved by the City Engineer and the Mayor. In the City of Albuquerque, the revision became effective on April 7, 1993. Bernalillo County also adopted the revision as the standard for design of flood and drainage control, effective April 7, 1993. The revised Section 22.2, Hydrology is to be regarded as the principal reference for hydrologic design in the City of Albuquerque and Bernalillo County.

The Drainage Design Criteria Committee wish to acknowledge the assistance of the many individuals who reviewed the document. In particular we wish to thank Richard Leonard, Brian Burnett and Dwayne Sheppard for their work on the Committee.

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INTRODUCTION

There have been many methods used in Albuquerque and Bernalillo County to compute runoff volumes, peak flow rates and runoff hydrographs from drainage basins. Any methodology used should be based on measurable conditions, be as simple as possible and produce accurate reproducible results. The methods, graphs, and tables which follow will be used by the City of Albuquerque, Bernalillo County and AMAFCA staff in the review and evaluation of development plans and drainage management plans.

Two basic methods of analysis are presented herein:

a) **PART A** - describes a simplified procedure for smaller watersheds based on the Rational Method and initial abstraction/uniform infiltration precipitation losses. The procedure is applicable to watersheds up to 40 acres in size, but the procedure may be extended to include larger watersheds with some limitations.

b) **PART C** - describes a unit hydrograph procedure which uses a version of the U.S.D.A. Agricultural Research Service HYMO computer program, modified to utilize initial abstraction/uniform infiltration precipitation losses. The AHYMO computer program developed by the Albuquerque Metropolitan Arroyo Flood Control Authority (AMAFCA), and the simplified input procedures available with this program, are also described. This procedure is applicable for small and large watersheds.

In addition to these procedures, **PART D** describes a modification of the **PART C** procedures to compute a Probable Maximum Flood. This has special application to the design of dams.

PART B describes the computation of time of concentration and time to peak which are used in PART A, PART C and PART D.

There may be conditions in which the procedures and analysis tools described in PART A, PART C or PART D are not applicable or optimal for design. **PART E** describes some additional analysis procedures and some criteria under which alternate procedures will be evaluated.

PART F contains a tabulated list of definitions of symbols used in this Section of the D.P.M. and a bibliography.

PART G contains the input and output files from the examples in PARTS C and D which utilize the HYMO computer program.

PART A - PROCEDURE FOR 40 ACRE AND SMALLER BASINS

A simplified procedure for projects with sub-basins smaller than 40 acres has been developed based on initial abstraction/uniform infiltration precipitation losses and Rational Method procedures. For this procedure, Bernalillo County has been divided into four (4) Precipitation Zones.

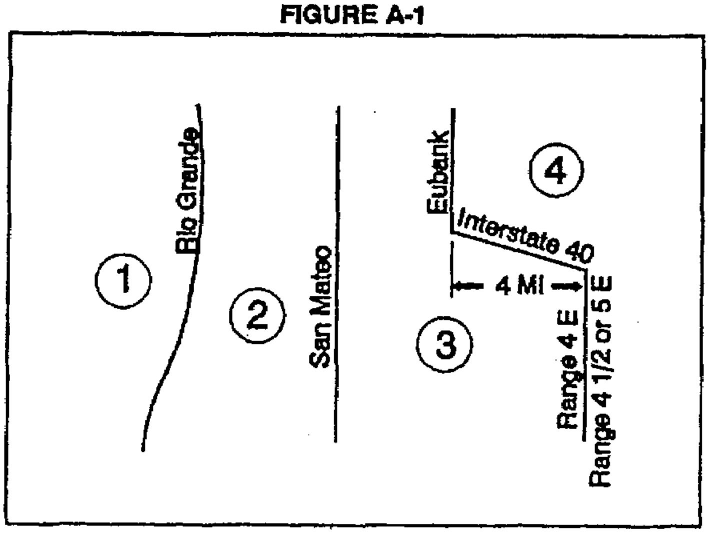
A.1 PRECIPITATION ZONES

Bernalillo County's four precipitation zones are indicated in TABLE A-1 and on FIGURE A-1.

TABLE A-1. PRECIPITATION ZONES

Zone	Location
1	West of the Rio Grande
2	Between the Rio Grande and San Mateo
3	Between San Mateo and Eubank, North of Interstate 40; and between San Mateo and the East boundary of Range 4 East, South of Interstate 40
4	East of Eubank, North of Interstate 40; and East of the East boundary of Range 4 East, South of Interstate 40

FIGURE A-1



Where a watershed extends across a zone boundary, use the zone which contains the largest portion of the watershed.

A.2 DESIGN STORM

The principal design storm is the 100-year 6-hour event defined by the NOAA Atlas 2, Precipitation-Frequency Atlas of the Western United States, Vol. IV - New Mexico. Assume an AMC II condition (a normally dry watershed). For design of retention or detention ponds, storms of 24-hour or longer duration many be required. The 24-hour event is defined by the NOAA Atlas 2. The 4-day and 10-day events can be obtained using the procedures in S.C.S. TSC Technical Note-Hydrology, PO-6 (Rev. 2) The 100-year 60-minute depth is computed by the following formula from Table 11 of NOAA Atlas 2:

$$P_{60} = 0.494 + 0.755 * (P_{360} * P_{360} / P_{1440}) \qquad \text{(a-1)}$$

TABLE A-2. DEPTH (INCHES) AT 100-YEAR STORM					
Zone	P_{60}	P_{360}	P_{1440}	P_{4days}	P_{10days}
1	1.87	2.20	2.66	3.12	3.67
2	2.01	2.35	2.75	3.30	3.95
3	2.14	2.60	3.10	3.95	4.90
4	2.23	2.90	3.65	4.70	5.95

The 2-year 60-minute depth is computed by the following formula from NOAA Atlas 2:

$$P_{60\text{-}2} = -0.011 + 0.942 * (P_{360\text{-}2} * P_{360\text{-}2} / P_{1440\text{-}2}) \qquad \text{(a-2)}$$

Based on fitting a logarithmic curve to the values in Table 12 of NOAA Atlas 2, the 12-minute (0.2 hour) depth was computed to be 50.24 percent of the 60-minute depth:

$$P_{12} = 0.5024 * P_{60} \qquad \text{(a-3)}$$

For certain applications (e.g., street drainage, low flow channels and sediment transport) storms of greater frequency than the 100-year storm must be considered. To estimate precipitation at return periods other than 100 years, multiply the 360-minute or 1440-minute 100-year precipitation amounts by the factors in TABLE A-3.

TABLE A-3. RETURN PERIOD FACTORS	
Return Period (years)	**Factor**
50	0.900
25	0.800
10	0.667
5	0.567
2	0.434

Example A-1

Find the 10-year, 6-hour storm depth for Zone 2.

$P_{360\text{-}10} = 2.35 * 0.667 = 1.57$ inches

Example A-2

Find the 2-year, 1-hour storm depth for Zone 3.

$P_{360\text{-}2} = 2.60 * 0.434 = 1.128$ inches

$P_{1440\text{-}2} = 3.10 * 0.434 = 1.345$ inches

$$P_{60\text{-}2} = -0.011 + 0.942 * (P_{360\text{-}2} * P_{360\text{-}2} / P_{1440\text{-}2})$$
$$= -0.011 + 0.942*(1.128*1.128/1.345)$$
$$= 0.880 \text{ inches}$$

A.3 LAND TREATMENTS

All land areas are described by one of four basic land treatments or by a combination of the four land treatments.

Land treatments are given in TABLE A-4.

TABLE A-4. LAND TREATMENTS	
Treatment	**Land Condition**
A	Soil uncompacted by human activity with 0 to 10 percent slopes. Native grasses, weeds and shrubs in typical densities with minimal disturbance to grading, groundcover and infiltration capacity.
B	Irrigated lawns, parks and golf courses with 0 to 10 percent slopes. Native grasses, weeds and shrubs, and soil uncompacted by human activity with slopes greater than 10 percent and less than 20 percent.
C	Soil compacted by human activity. Minimal vegetation. Unpaved parking, roads, trails. Most vacant lots. Gravel or rock on plastic (desert landscaping). Irrigated lawns and parks with slopes greater than 10 percent. Native grasses, weeds and shrubs, and soil uncompacted by human activity with slopes at 20 percent or greater. Native grass, weed and shrub areas with clay or clay loam soils and other soils of very low permeability as classified by SCS Hydrologic Soil Group D.
D	Impervious areas, pavement and roofs.
Most watersheds contain a mix of land treatments. To determine proportional treatments, measure respective subareas. In lieu of specific measurement for treatment D, the areal percentages in TABLE A-5 may be employed.	

TABLE A-5. PERCENT TREATMENT D (Impervious)	
Land Use	**Percent**
Commercial*	90
Single Family Residential N=units/acre, N≤6	$7*\sqrt{((N*N)+(5*N))}$ (a-4)
Multiple Unit Residential Detached* Attached*	 60 70
Industrial Light* Heavy*	 70 80
Parks, Cemeteries	7
Playgrounds	13
Schools	50
Collector & Arterial Streets	90
*Includes local streets	

TABLE A-5 does not provide areal percentages for land treatments A, B and C. Use of TABLE A-5 will require additional analysis to determine the appropriate areal percentages of these land treatments.

Backyard retention ponds, and other small on-site ponding, may have the effect of reducing runoff from impervious areas. Where it can be clearly demonstrated that backyard and small on-site retention ponding currently exist, impervious and/or pervious areas which drain to such ponds ~~may~~ can be given credit towards their determination of peak rates of runoff and runoff volumes from the development. ~~considered to be in land treatment A~~. ~~Application of backyard ponding is not normally applicable to more than 35 percent of the area in land treatment D (impervious). Allowance for backyard ponding will not be considered for new developments and future development.~~

A.4 ABSTRACTIONS

Initial abstraction is the precipitation depth which must be exceeded before direct runoff begins. Initial abstraction may be intercepted by vegetation, retained in surface depressions, or absorbed on the watershed surface. Initial abstractions are shown in TABLE A-6.

TABLE A-6. INITIAL ABSTRACTION (IA)	
Treatment	**Initial Abstraction (inches)**
A	0.65
B	0.50
C	0.35
D	0.10

Infiltration is the only significant abstraction after the initial abstraction. After initial abstraction is satisfied, treat infiltration as a constant loss rate as specified in TABLE A-7.

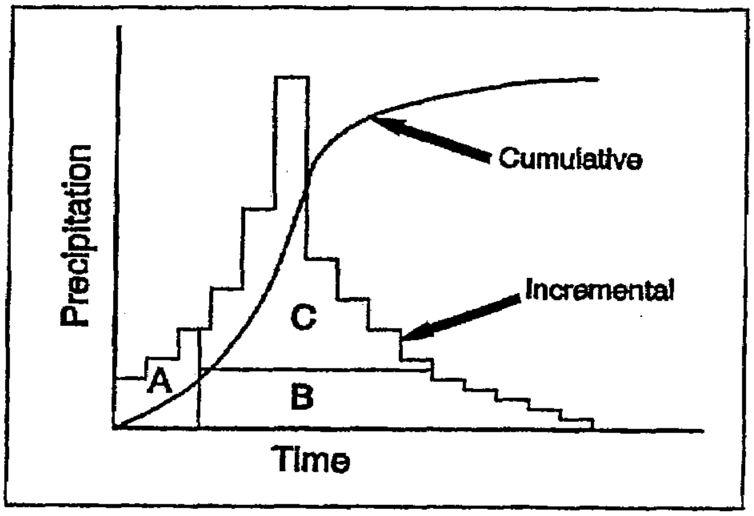
TABLE A-7. INFILTRATION (INF)	
Treatment	**Loss Rate (inches/hour)**
A	1.67
B	1.25
C	0.83
D	0.04*
* Treatment D infiltration rate is applicable from 0 to 3 hours; use uniform reduction from 3 to 6 hours, with no infiltration after 6 hours.	

Runoff from a previous event can saturate a channel bed, rendering it minimally pervious for several days. Do not anticipate additional bed losses for design purposes.

A.5 EXCESS PRECIPITATION & VOLUMETRIC RUNOFF

Excess precipitation, E, is the depth of precipitation remaining after abstractions are removed. Excess precipitation does not depend on watershed area. Excess precipitation is determined by subtracting the initial abstraction and infiltration from the design storm hydrograph. FIGURE A-2 illustrates the development of excess precipitation. The curved line plots cumulative precipitation. Precipitation intensities (in/hr) are shown as a histogram. Initial abstraction is area A. The horizontal line is at a height corresponding to the infiltration rate. Infiltration loss is area B. The remaining histogram, area C, is excess precipitation.

FIGURE A-2



Excess precipitation, E, by zone and treatment is summarized in TABLE A-8.

(NOTE: In this table and several tables which follow, corresponding values for 2- and 10- year storms are shown in brackets below each 100-year value)

TABLE A-8. EXCESS PRECIPITATION, E (INCHES) - 6 HOUR STORM				
Zone	Treatment 100-YR [2-YR, 10-YR]			
	A	B	C	D
1	0.44 [0.00, 0.08]	0.67 [0.01, 0.22]	0.99 [0.12, 0.44]	1.97 [0.72, 1.24]
2	0.53 [0.00, 0.13]	0.78 [0.02, 0.28]	1.13 [0.15, 0.52]	2.12 [0.79, 1.34]
3	0.66 [0.00, 0.19]	0.92 [0.06, 0.36]	1.29 [0.20, 0.62]	2.36 [0.89, 1.50]

4	0.80 [0.02, 0.28]	1.08 [0.11, 0.46]	1.46 [0.27, 0.73]	2.64 [1.01, 1.69]

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To determine the volume of runoff,

1) Determine the area in each treatment, A_A, A_B, A_C, A_D

2) Compute the weighted excess precipitation, E

$$\text{Weighted E} = \frac{E_A A_A + E_B A_B + E_C A_C + E_D A_D}{A_A + A_B + A_C + A_D} \qquad \text{(a-5)}$$

3) Multiply the weighted E by the watershed area.

$$V_{360} \text{ (as volume)} = \text{weighted E* } (A_A + A_B + A_C + A_D) \qquad \text{(a-6)}$$

EXAMPLE A-3
Find the 100-year V_{360} for 30 acres in zone 1. Eight acres are treatment A, 10 acres are treatment B, 5 acres are treatment C, and 7 acres are treatment D.
Weighted E = ((8 * 0.44) + (10 * 0.67) + (5 * 0.99) + (7 * 1.97)) / 30 = 0.965 inches
Volume = (0.965 * 30) / 12 = 2.41 acre-ft. = V_{360}

For ponds which hold water for longer than 6 hours, longer duration storms are required to establish runoff volumes. Since the additional precipitation is assumed to occur over a long period, the additional volume is based on the runoff from the impervious areas only.

For 24-hour storms:

$$V_{1440} = V_{360} + A_D * (P_{1440} - P_{360}) / 12 \text{ in/ft} \qquad \text{(a-7)}$$

For 4-day storms:

$$V_{4DAYS} = V_{360} + A_D * (P_{4DAYS} - P_{360}) / 12 \text{ in/ft} \qquad \text{(a-8)}$$

For 10-day storms:

$$V_{10DAYS} = V_{360} + A_D * (P_{10DAYS} - P_{360}) / 12 \text{ in/ft} \qquad \text{(a-9)}$$

EXAMPLE A-4
Find the 100-year 24-hour and 4-day runoff volume, V_{1440} and V_{4days}, for the area in Example A-3.
V_{360} = 2.41 acre-feet
V_{1440} = 2.41 + 7 ac * (2.66 - 2.20) / 12 = 2.68 acre-feet
V_{4DAYS} = 2.41 + 7 ac * (3.12 - 2.20) / 12 = 2.95 acre-feet

A.6 PEAK DISCHARGE RATE FOR SMALL WATERSHEDS

Small watersheds are less than or equal to 40 acres.

Peak Discharge

Using a 0.2-hour (12-minute) time of concentration, peak discharge, Q_P, per acre is the volume of excess precipitation in the heaviest 12-minute portion of the storm, divided by the time increment 12 minutes, and multiplied by an attenuation factor. The attenuation factor (0.59 for treatment A, 0.67 for treatment B, 0.75 for treatment C and 0.93 for treatment D) describes the effect of routing. Determine the peak discharge using the values in TABLE A-9, which have been adjusted to consider the effects of initial abstraction.

TABLE A-9. PEAK DISCHARGE (CFS/ACRE)

Zone	Treatment 100-YR [2-YR, 10-YR]			
	A	**B**	**C**	**D**
1	1.29 [0.00, 0.24]	2.03 [0.03, 0.76]	2.87 [0.47, 1.49]	4.37 [1.69, 2.89]
2	1.56 [0.00, 0.38]	2.28 [0.08, 0.95]	3.14 [0.60, 1.71]	4.70 [1.86, 3.14]
3	1.87 [0.00, 0.58]	2.60 [0.21,1.19]	3.45 [0.78, 2.00]	5.02 [2.04, 3.39]
4	2.20 [0.05, 0.87]	2.92 [0.38, 1.45]	3.73 [1.00, 2.26]	5.25 [2.17, 3.57]

To determine the peak rate of discharge,

1) Determine the area in each treatment, A_A, A_B, A_C and A_D.

2) Multiply the peak rate for each treatment by the respective areas and sum to compute the total Q_P.

$$\text{Total } Q_P = Q_{PA}A_A + Q_{PB}A_B + Q_{PC}A_C + Q_{PD}A_D \qquad \text{(a-10)}$$

Example A-5
Find 100-year Q_P for 14 acres in zone 1. The four land treatments are: 3 acres in treatment A, 5 acres in treatment B, 2 acres in treatment C and 4 acres in treatment D.
Total $Q_P = (1.29 * 3) + (2.03 * 5) + (2.87 * 2) + (4.37 * 4) = 37.24$ cfs

3) Approximately the same results can be achieved by a Rational Method solution. The 0.2-hour (12-minute) peak intensities, I, are given in TABLE A-10 and Rational Method coefficients, C, are given in TABLE A-11.

$$\text{Total } Q_P = (C_A * I * A_A) + (C_B * I * A_B)$$

$$+ (C_C * I * A_C) + (C_D * I * A_D) \qquad \text{(a-11)}$$

TABLE A-10. PEAK INTENSITY (IN/HR at t_c = 0.2 hour)

Zone	Intensity 100-YR [2-YR, 10-YR]
1	4.70 [1.84, 3.14]
2	5.05 [2.04, 3.41]
3	5.38 [2.21, 3.65]
4	5.61 [2.34, 3.83]

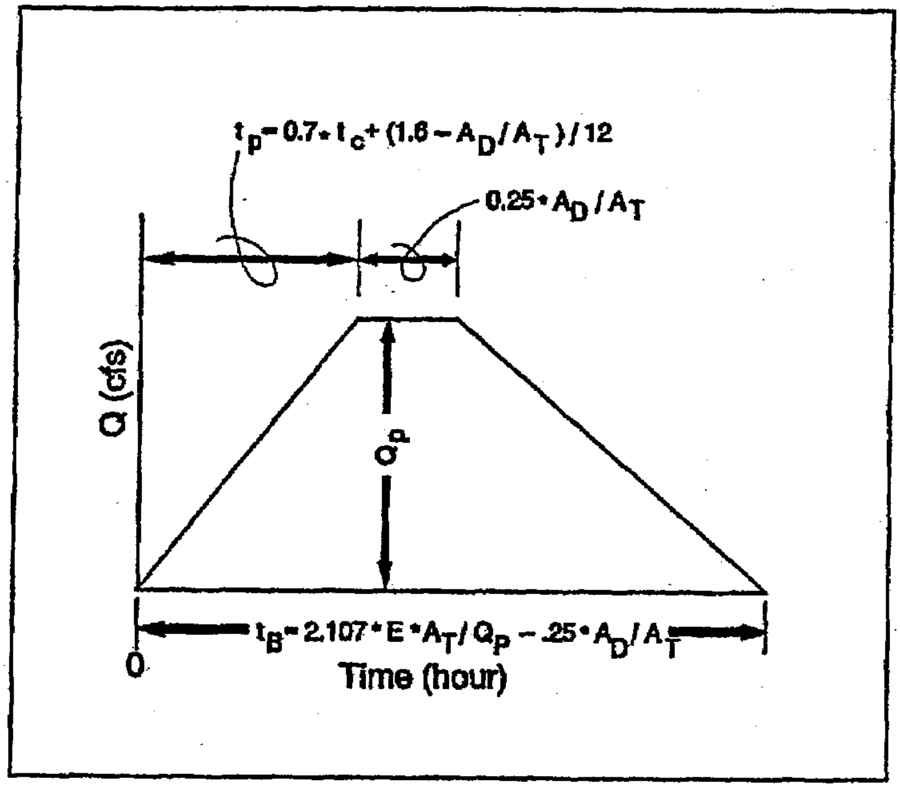
TABLE A-11. RATIONAL METHOD COEFFICIENT, C				
Zone	Treatment			100-YR [2-YR, 10-YR]
	A	B	C	D
1	0.27 [0.00, 0.08]	0.43 [0.02, 0.24]	0.61 [0.26, 0.47]	0.93 [0.92, 0.92]
2	0.31 [0.00, 0.11]	0.45 [0.04, 0.28]	0.62 [0.29, 0.50]	0.93 [0.91, 0.92]
3	0.35 [0.00, 0.16]	0.48 [0.10, 0.33]	0.64 [0.35, 0.55]	0.93 [0.92, 0.93]
4	0.39 [0.02, 0.23]	0.52 [0.16, 0.38]	0.66 [0.43, 0.59]	0.94 [0.93, 0.93]

(Note the quote from the ASCE Manual and Report on Engineering Practice No. 37 (1969): The commonly reported Rational C values "are applicable for storms to 5- to 10-yr frequencies. Less frequent, higher intensity storms will require the use of higher coefficients because infiltration and other losses have a proportionally smaller effect on runoff." Thus higher C's realized under heavy precipitation might be expected.)

Example A-6
Recompute Example A-5 using the Rational Method. Q = C I A = (0.27 * 4.70 *3) + (0.43 * 4.70 * 5) + (0.61 * 4.70 * 2) + (0.93 * 4.70 * 4) = 37.13 cfs

Continue the peak for 0.25 * A_D / A_T hours. When A_D is zero, the hydrograph will be triangular. When A_D is not zero, the hydrograph will be trapezoidal. FIGURE A-3 shows the hydrograph in graphic form.

FIGURE A-3



Example A-8

Determine the hydrograph for Example A-5.

A_T = 14.0 acres A_D = 4.0 acres t_C = 0.2 hour Q_P = 37.24 cfs

E = ((3 * .44) + (5 * .67) + (2 * .99) + (4 * 1.97)) / (3 + 5 + 2 + 4) = 1.038 inches

t_P = (0.7 * 0.2) + (1.6 - (4 / 14)) / 12) = 0.2495 hours

t_B = (2.017 * 1.038 * 14 / 37.24) - (0.25 * 4 / 14) = 0.7157 hours

Duration of peak = 0.25 * 4 / 14 = 0.0714 hours

PART B - TIME OF CONCENTRATION, LAG TIME, AND TIME TO PEAK

There is a delay, after a brief heavy rain over a watershed, before the runoff reaches its maximum. The length of time it takes for runoff from a watershed to reach an analysis point effects the peak runoff rate, with shorter times producing higher peak flow for a constant runoff volume. The velocity at which water can flow through a watershed and the length of flow path are used to determine the time factors. Time of concentration, lag time, and time to peak are three related watershed parameters that are used to determine peak rates of runoff.

B.1 DEFINITIONS

The three time parameters used are defined as follows:

time of concentration (t_c) = time it takes for runoff to travel from the hydraulically most distant part of the watershed basin to the basin outlet or point of analysis

Lag time (L_G) = time from the center of unit rainfall excess to the time that 50 percent of the volume of unit runoff from the drainage basin has passed the concentration point or point of analysis.

time to peak (t_p) = time from the beginning of unit rainfall excess to the time of the peak flow of the unit runoff hydrograph.

The three time parameters can be computed using the procedures identified in this section. The peak discharge rates and intensity factors identified in TABLES A-9 and A-10 (PART A) were computed using a time of concentration (t_c) of 0.2 hour. The procedures in Part C require the computation of time to peak (t_p) as specified herein.

B.2 COMPUTATION OF TIME OF CONCENTRATION

Three different equations are used to compute time of concentration (t_c) for larger watersheds. For subbasin reach lengths shorter than 4000 feet the SCS Upland Method is used; for subbasin reach lengths longer than 12000 feet the USDI Bureau of Reclamation lag time equation is used. A transition equation is used for subbasin reach lengths between 4000 and 12000 feet.

Consideration should be given to splitting large watersheds into smaller subbasins with reach lengths less than 4000 feet. Smaller subbasins will allow more accurate modeling of channels and basin topography, and should provide for greater modeling accuracy.

1). For subbasin reach lengths less than 4000 feet:

Compute time of concentration, t_c (hours), for the entire (pervious and impervious) watershed by the SCS Upland Method, the sum of the travel times in the subreaches comprising the longest flow path to the watershed outlet.

$$t_c = (L_1 / V_1 + L_2 / V_2 + ... + L_x / V_x) / 3600 \text{ sec/hour} \qquad \text{(b-1)}$$

and, $(L_1 + L_2 + ... + L_x) < 4000$ feet

where L_x is the subreach length (feet) and v is the velocity (feet/sec) in that subreach, as determined by the following equation:

$$v = K * \sqrt{(s * 100)} = 10 * K * \sqrt{(s)} \qquad \text{(b-2)}$$

where s is the slope in foot per foot, and K depends upon the conveyance condition, as shown in TABLE B-1. If t_C is computed to be less than 0.2 hours, use $t_C = 0.2$ hours.

TABLE B-1. CONVEYANCE FACTORS

K	Conveyance Condition
0.7	Turf, landscaped areas and undisturbed natural areas (sheet flow* only).
1	Bare or disturbed soil areas and paved areas (sheet flow* only).
2	Shallow concentrated flow (paved or unpaved).
3	Street flow, storm sewers and natural channels, and that portion of subbasins (without constructed channels) below the upper 2000 feet for subbasins longer than 2000 feet.
4	Constructed channels (for example: riprap, soil cement or concrete lined channels).

* Sheet flow is flow over plane surfaces, with flow depths up to 0.1 feet.
Sheet flow applies only to the upper 400 feet (maximum) of a subbasin.

For composite reaches, where this basin slope is uniform, the composite basin conveyance condition, K, can be computed using the following equation:

$$K = L / (L_1 / K_1 + L_2 / K_2 + ... + L_X / K_X) \qquad \text{(b-3)}$$

where $L = L_1 + L_2 + ... + L_X$

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For composite reaches where the basin slope is <u>not</u> uniform, the composite basin conveyance condition, K, can be computed using the following equation:

$$K = (L / \sqrt{s}) / (L_1 / (K_1 * \sqrt{s_1}) + L_2 / (K_2 * \sqrt{s_2}) + ... + L_x / (K_x * \sqrt{s_x})) \qquad \text{(b-4)}$$

where: $L = L_1 + L_2 + ... + L_x$

and, $$s = (L_1 * s_1 + L_2 * s_2 + ... + L_x * s_x) / L \qquad \text{(b-5)}$$

2.) For subbasin reach lengths between 4000 and 12000 feet:

Compute the time of concentration, t_C (hours), for the entire watershed using the following equation:

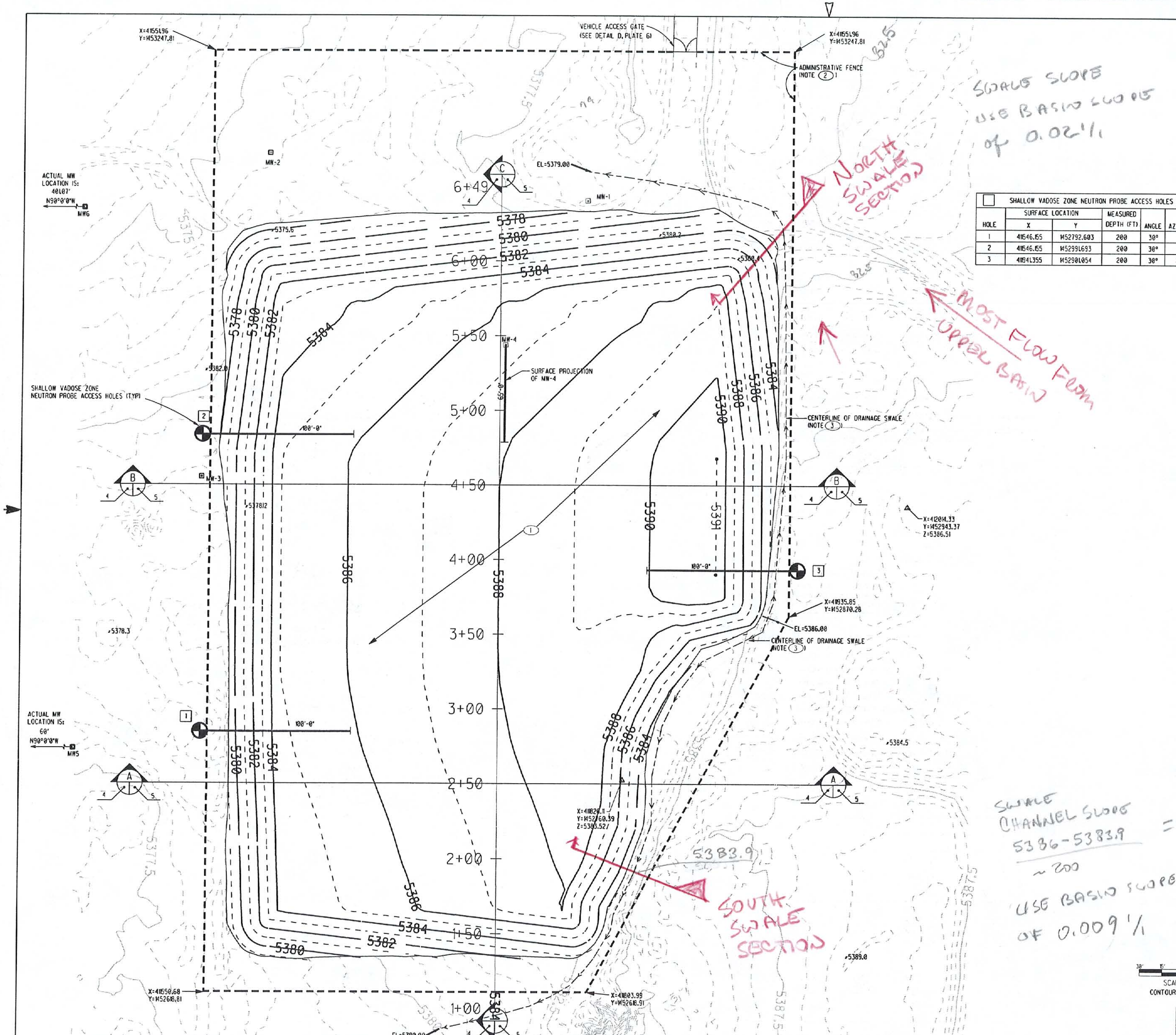
$$t_C = ((12000 - L) / (72000 * K * s^{0.5})) + ((L - 4000) * K_N * (L_{CA} / L)^{0.33} / (552.2 * s^{0.165})) \qquad \text{(b-6)}$$

where:

K	=	Conveyance factor from TABLE B-1. For composite reaches, K is computed using equation b-3 or b-4.
L	=	distance of longest watercourse, in feet.
L_{CA}	=	distance along L from point of concentration to a point opposite centroid of drainage basin, in feet.
s	=	overall slope of L, in foot per foot. For composite reaches s is computed using equation b-5.
K_N	=	a basin factor based on an estimate of the weighted, by stream length, average Manning's n value for the principal watercourses in the drainage basin. For the Albuquerque area, values of K_N may be estimated from TABLE B-2.

TABLE B-2. LAG EQUATION BASIN FACTORS

K_N	Basin Condition
0.042	Mountain Brush and Juniper
0.033	Desert Terrain (Desert Brush)
0.025	Low Density Urban (Minimum improvements to watershed channels)
0.021	Medium Density Urban (Flow in streets, storm sewers and improved channels)
0.016	High Density Urban (Concrete and rip-rap lined channels)



SHALLOW VADOSE ZONE NEUTRON PROBE ACCESS HOLES					
HOLE	SURFACE LOCATION X	SURFACE LOCATION Y	MEASURED DEPTH (FT)	ANGLE	AZIMUTH
1	41646.65	1452792.603	200	30°	90°
2	41646.65	1452991.693	200	30°	90°
3	411941.355	1452901.054	200	30°	270°

GENERAL NOTES

1. BORROW SITE FOR NATIVE SOIL LAYER FILL AND TOPSOIL LAYER IS APPROXIMATELY 1.5 MILES SOUTH OF THE PROJECT AREA.
2. NATIVE SOIL LAYER FILL SHALL BE OBTAINED FROM TA-3 BORROW PITS. APPROXIMATELY 13,200 CUBIC YARDS OF FILL SHALL BE REQUIRED FOR THE NATIVE SOIL LAYER. FILL SHALL BE PLACED IN MAXIMUM 8-INCH LOOSE LIFTS TO ATTAIN MAXIMUM 6-INCH COMPACTED LIFT THICKNESS. FILL SHALL BE COMPACTED TO NOT LESS THAN 90 PERCENT OF MAXIMUM DRY DENSITY AT -2 TO +2 PERCENT OF OPTIMUM MOISTURE CONTENT, AS DETERMINED BY ASTM D698 (STANDARD PROCTOR TESTING). ANY GRADE STAKES USED ON THE PROJECT SHALL BE REMOVED AND BACKFILLED WITH COVER MATERIAL TO MEET CONSTRUCTION SPECIFICATIONS.
3. THE TOPSOIL LAYER SHALL BE PLACED IN A MAXIMUM 8-INCH LOOSE LIFT. THE TOPSOIL LAYER SHALL BE MINIMALLY COMPACTED TO NOT LESS THAN 80 PERCENT AND NOT GREATER THAN 90 PERCENT OF MAXIMUM DRY DENSITY AT -2 TO +2 PERCENT OF OPTIMUM MOISTURE CONTENT, AS DETERMINED BY ASTM D698 (STANDARD PROCTOR TESTING). TOPSOIL SHALL BE ADMIXED 25 PERCENT BY VOLUME WITH 3/8-INCH CRUSHED GRAVEL (ASTM D448, SIZE #8). APPROXIMATELY 3,900 CY WILL BE REQUIRED FOR THE TOPSOIL LAYER.
4. BIOINTRUSION LAYER MATERIALS: THE BIOINTRUSION BARRIER MATERIAL SHALL BE CONSTRUCTED USING A GRADED ROCK RIPRAP. RIPRAP SIZE SHALL BE OF STONE SIZE SO THAT 50 PERCENT OF THE PIECES, BY WEIGHT, SHALL BE LARGER THAN THE D50 SIZE(4"). THE WELL GRADED MATERIAL SHALL BE A MIXTURE COMPOSED PRIMARILY OF LARGER STONE SIZES BUT WITH A SUFFICIENT MIXTURE OF OTHER SIZES TO FILL THE SMALLER VOIDS BETWEEN THE STONES. THE DIAMETER OF THE LARGEST STONE SIZE IN SUCH A MIXTURE SHALL BE 6" (1.5 TIMES) THE D50 SIZE OF 4". THE THICKNESS OF THE BIOINTRUSION BARRIER MATERIAL LAYER SHALL BE A MINIMUM OF 1' AND A MAXIMUM OF 1.25'.

THE BIOINTRUSION LAYER SHALL BE OBTAINED FROM A LOCAL SUPPLIER AND STOCKPILED SOUTH OF THE SITE BY THE OPERATOR FOR THE CONTRACTOR'S USE.

KEYED NOTES

(1) THE FINAL COVER CONTOURS INDICATE TOP OF THE FINAL COVER.

(2) CONTRACTOR SHALL INSTALL AN ADMINISTRATIVE FENCE AROUND PERIMETER OF CONSTRUCTED LANDFILL COVER. ADMINISTRATIVE FENCE SHALL BE CONSTRUCTED ACCORDING TO DETAIL D, PLATE 6.

(3) CONTRACTOR SHALL CONSTRUCT A DRAINAGE SWALE IN ACCORDANCE WITH DETAIL C, PLATE 6. DRAINAGE SWALE SHALL BE CONSTRUCTED TO ENSURE POSITIVE DRAINAGE USING ELEVATIONS SHOWN ON THIS PLAN AS A GENERAL GUIDE.

SEEDING PLAN

1. SEEDING SHALL COMPLY WITH CONSTRUCTION SPECIFICATION 02930, RECLAMATION SEEDING AND MULCHING.
2. THE FOLLOWING SEED MIX SHALL BE USED FOR SEEDING OF THE FINAL GRADE, BORROW LOCATION, LAYDOWN AREAS, AND OTHER LOCATIONS IMPACTED BY CONSTRUCTION ACTIVITIES:

SEED SPECIES	SEEDING RATE PURE LIVE SEED (POUNDS PER ACRE)
BLACK GRAMA	6.0
GALLETA GRASS	8.0
RING MUHLY	3.0
SPIKE DROPSEED	3.0

ESTIMATED BORROW QUANTITES	
TOPSOIL LAYER	3900 CY
BIOINTRUSION LAYER	4900 CY
NATIVE SOIL LAYER	13,200 CY

LEGEND

5384.5	EXISTING INDEX CONTOUR
	EXISTING INTERMEDIATE CONTOUR
	FINAL ADMINISTRATIVE FENCE
5384.5	FINAL COVER INDEX CONTOUR
	FINAL COVER INTERMEDIATE CONTOUR
MW-4	GROUNDWATER MONITORING WELL
	DRAINAGE SWALE CENTERLINE
1	SHALLOW VADOSE ZONE NEUTRON PROBE ACCESS HOLES
	PROJECT BENCHMARKS

SCALE 1"=30'
CONTOUR INTERVAL 0.5'

P.O. OR W.O. / PROJECT NO.	REV	DATE	DESCRIPTION	DWN	CKD	APP
	B	7/29/05	ISSUED FOR VOLUNTARY CORRECTIVE MEASURE	M.T.D.	G.A.W.	H.C.S.
	A	9/23/99	ISSUED FOR REGULATORY REVIEW	S.F.G.	R.A.W.	H.C.S.

U.S. DEPARTMENT OF ENERGY
KIRTLAND AREA OFFICE
ALBUQUERQUE, NEW MEXICO

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE, NEW MEXICO

FINAL COVER

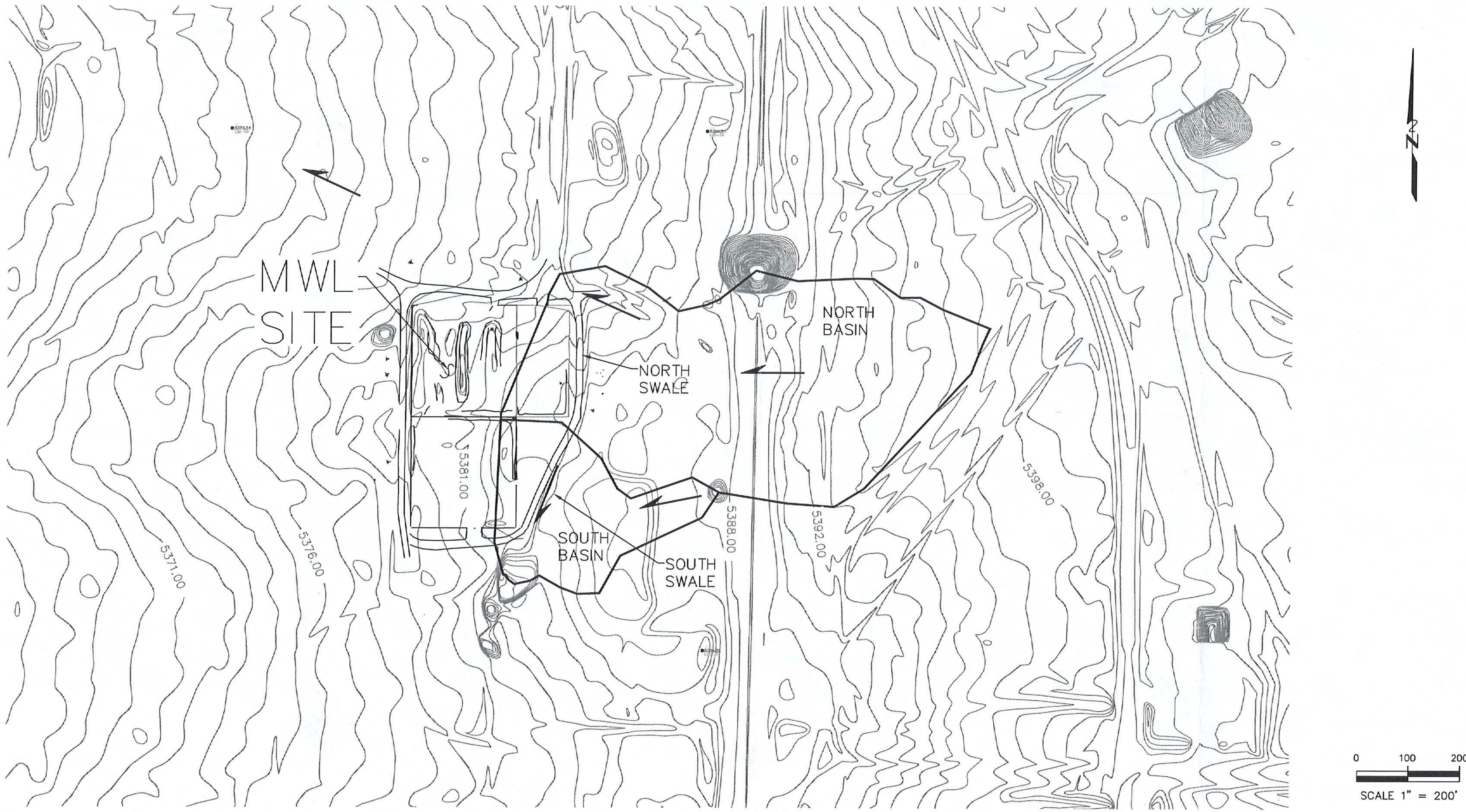
MIXED WASTE LANDFILL FINAL COVER GRADING PLAN

P.O. OR W.O.	
PROJECT NO.	
DRAWN BY	M.T.D./S.F.G.
CHECKED BY	G.A.W.
APPROVED BY	H.C.S./xx
DATE	07.29.05

CAD DRAWING
COMPUTER SYSTEMS DEPT. 7901
SITE UTILITIES DEPT. 7821/7823
FILE NAME: 999997A6.91
REFERENCE FILES:

SIZE D+ DRAWING NO./SHEET 999997/A6.91 PLATE 4

EXHIBIT 1



DIRECTION OF FLOW

BASIN BOUNDARY

URS

6501 AMERICAS PARKWAY N.E., SUITE 900
ALBUQUERQUE, NEW MEXICO 87110
(505) 855-7500 FAX: (505) 855-7555

TOPOGRAPHICAL MAP
FOR MIXED WASTE
EXHIBIT #2

MWL SITE
AS OF DECEMBER, 2006

SHEET 1 OF 1

APPENDIX A

Sampling and Analysis Plan for Soil Gas Volatile Organic Compounds, Tritium, and Radon at the Mixed Waste Landfill

SANDIA NATIONAL LABORATORIES/NEW MEXICO

DECEMBER 2006

APPENDIX A

Sampling and Analysis Plan for Soil Gas Volatile Organic Compounds, Tritium, and Radon at the Mixed Waste Landfill

SANDIA NATIONAL LABORATORIES/NEW MEXICO

DECEMBER 2006

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Acronyms and Abbreviations

AOP	Administrative Operating Procedure
bgs	below ground surface
DQO	data quality objective
EB	equipment blank
FOP	field operating procedure
GC/MS	gas chromatograph/mass spectrometer
MWL	Mixed Waste Landfill
NMED	New Mexico Environment Department
pCi/m2/s	picocuries per meter squared per second
PID	photoionization detector
ppm	part(s) per million
QA/QC	quality assurance/quality control
SAP	sampling and analysis plan
SMO	Sample Management Office
SNL/NM	Sandia National Laboratories/New Mexico
SOW	Statement of work
TBD	to be determined
VOCs	volatile organic compounds

1.0 Executive Summary

The Mixed Waste Landfill (MWL) is located in the north-central part of Sandia National Laboratories/New Mexico (SNL/NM) Technical Area III. Soil gas volatile organic compound (VOC) and tritium sampling was conducted at the MWL in 1993 and 1994 during a Phase 2 RCRA Investigation, but no recent data regarding VOC concentrations in soil gas and tritium in soils has been collected. This Sampling and Analysis Plan was developed in response to a request by the New Mexico Environment Department (NMED) to obtain more current soil gas VOC and tritium data for the MWL. NMED has also requested that sampling for potential radon emissions from the MWL be completed. The NMED request was submitted in a letter dated November 20, 2006 and entitled "Notice of Disapproval: Mixed Waste Landfill Corrective Measures Implementation Work Plan, November 2005, and Requirement for Soil-Vapor Sampling and Analysis Plan, Sandia National Laboratories".

This sampling and analysis plan (SAP) has been prepared to meet the NMED request. SNL/NM proposes to collect soil gas VOC and tritium soil samples from six previous 1994 locations within the MWL, and from two background locations southwest of the landfill. SNL/NM also proposes to monitor for potential radon emissions by placing radon detectors at ten locations around the MWL perimeter after the final landfill cover is installed, and at two additional background locations southwest of the landfill.

It is anticipated that the soil gas VOC and tritium soil sampling will be completed in early 2007. Radon measurements will be conducted after the permanent perimeter fence around the MWL has been constructed. Analytical results for the soil gas VOC, tritium, and radon sampling will be summarized in two separate investigation reports that will be submitted to the NMED for review.

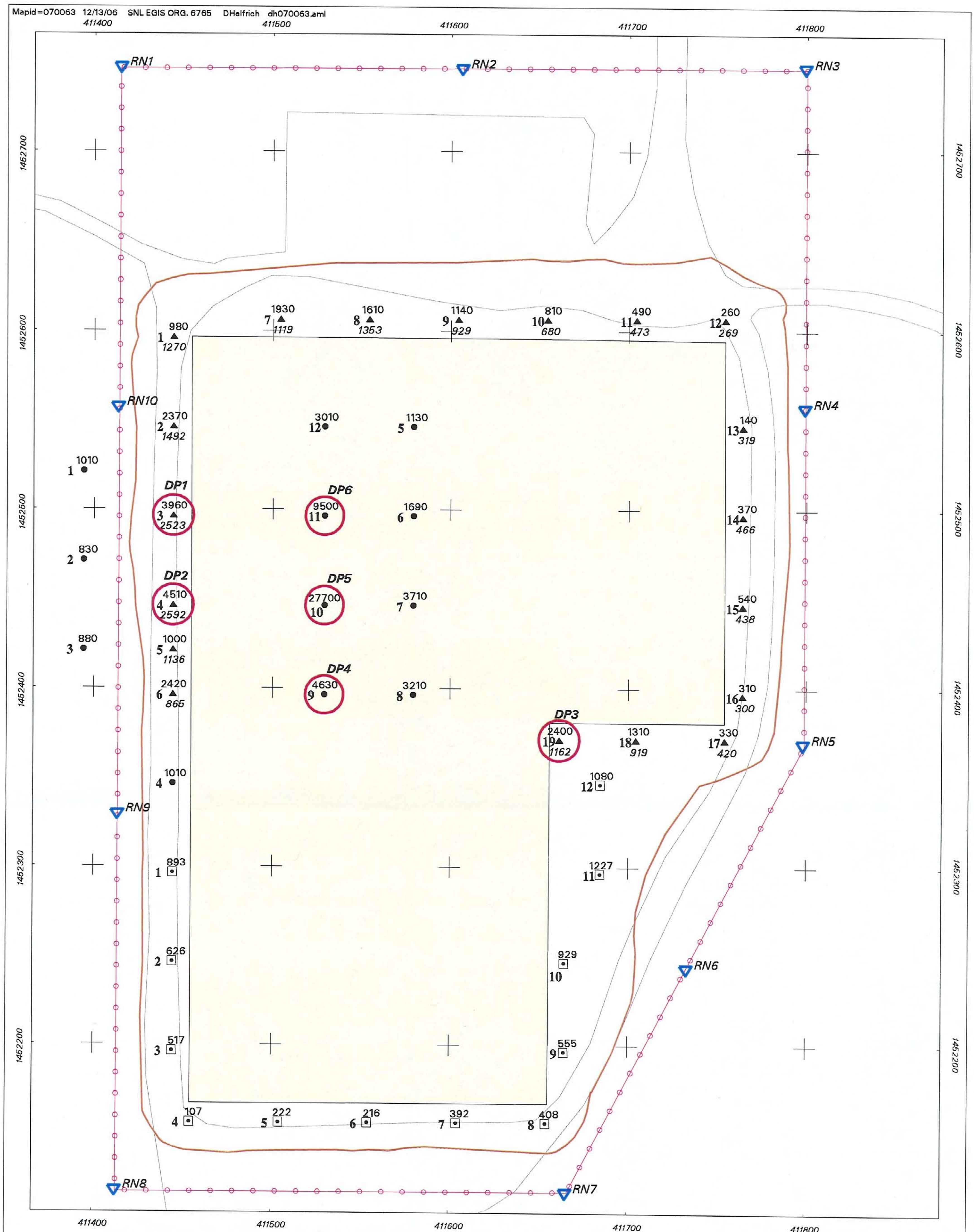
2.0 Introduction and Background Information

Active soil gas samples were collected from 43 locations in and around the MWL in June-October 1994, as shown on Figure 2-1. Soil gas samples were retrieved from target depths of 10 and 30 feet below ground surface (bgs) at each location with GeoProbe ™ soil gas collection equipment, and were collected in both 500 ml glass bulbs and SUMMA canisters. The glass bulb samples were analyzed with an on-site gas chromatograph/mass spectrometer (GC/MS), and the SUMMA canister samples were analyzed by an off-site commercial laboratory for VOCs by EPA Method TO-14.

Analytical results for the 1994 soil gas samples are presented and discussed in the "Report of the Mixed Waste Landfill Phase 2 RCRA Facility Investigation, Sandia National Laboratories, New Mexico" (SNL/NM September 1996). Eight individual VOCs were detected in the 10 and 30-ft samples, with total VOC concentrations ranging from 0.03 to 30.7 parts per million (ppm) in the 10-ft bgs samples, and from 0.107 to 27.7 ppm in the 30-ft bgs samples (Figure 2-1).

The Mixed Waste Landfill Corrective Measures Implementation Work Plan was written and submitted to the NMED Hazardous Waste Bureau in November 2005 (SNL/NM November 2005). NMED reviewed the document, and responded with a "Notice of Disapproval" letter dated November 20, 2006 (NMED November 2006). This letter described a number of deficiencies related to both the MWL cover, construction plans, performance and fate and transport modeling, and monitoring triggers. The letter also included a requirement for additional soil gas sampling at the landfill, as follows:

"As the Permittees are aware, most site characterization data for the MWL (other than groundwater data) dates before the mid 1990's. Because the rupturing of containers and leaking of their contents could have occurred since the mid 1990's, the NMED requires more current soil-gas data to help resolve this issue. The Permittees shall therefore collect and analyze active soil-gas samples taken at depths of 10 and 30 feet at a minimum of three locations within the landfill where previous sampling has detected the highest soil-gas concentrations in the past. The soil-gas samples shall be analyzed for volatile organic compounds, tritium, and radon. Pursuant to Section VI.A of the Order on Consent (April 29, 2004), the Permittees shall provide for approval to the NMED within 30 days of receipt of this letter a work plan to conduct the active soil-vapor sampling described above. The work plan shall be prepared in accordance with Section X.B of the Consent Order." (NMED November 2006).



Legend

6 ▲450	1994 First-round sample location, borehole number, and total soil gas VOC concentration at 30 feet(ppb)
4 ●720	1994 Second-round sample location, borehole number, and total soil gas VOC concentration at 30 feet(ppb)
1 ▣47	1994 Third-round sample location, borehole number, and total soil gas VOC concentration at 30 feet(ppb)
RN1	2007 Radon Track Etch sampling locations and name
DP1	2007 Re-sample location and new borehole name
	Current Unpaved Road
	Proposed Final Fence
	Proposed Toe of Landfill Cover
	SWMU 76, Former MWL Extent

Figure 2-1
1994 Soil Gas VOC Sampling Locations, Soil Gas VOC Concentrations at 30 Feet, and Proposed 2007 Soil Gas VOC, Tritium, and Radon Sampling Locations, Mixed Waste Landfill

0 60 120
Scale in Feet

0 14 28
Scale in Meters

Sandia National Laboratories, New Mexico
Environmental Geographic Information System

3.0 *Scope of Activities*

This SAP has been prepared to address the NMED requirement for additional sampling at the MWL. This document provides guidance and instructions for collecting and analyzing for VOCs in soil gas, tritium in soil moisture, and Radon flux at locations in and around the landfill. This SAP also presents specifications for field sampling, laboratory analysis, data validation and evaluation, and reporting. It is also designed to ensure that future soil gas VOC and tritium sampling procedures are consistent with past practices and produce defensible analytical results that can be compared to historical results. Analytical results for the new soil gas VOC samples will be compared to those results obtained from the 1994 samples to determine if significant changes in soil gas VOC concentrations have occurred in MWL subsurface soils since the 1994 samples were collected. Tritium activities in soil moisture that are detected in the new samples will also be compared to tritium activities detected in soil samples collected in 1994, and that were presented in the 1996 Phase 2 RFI report (SNL/NM September 1996). Ambient radon concentrations measured by Track-Etch radon detectors will be compared to the proposed trigger value of 4 pCi/L, presented in the "Probabilistic Fate and Transport Modeling of the Mixed Waste Landfill at Sandia National Laboratories" (Ho, C.H., et al February 2006).

3.1 Soil Gas VOC and Tritium Sampling Locations, Depths, and Frequency

One round of soil gas VOC and tritium soil moisture samples will be collected at depths of 10 and 30 feet below the original surface of the landfill. Since boreholes will be drilled through the recently-completed subgrade, the added thickness of the subgrade at each boring location will have to be accounted for, in order that the samples are collected from the same depths that were sampled in 1994. Samples will be collected from six MWL sampling locations where the highest soil gas VOC concentrations were detected at the 30-ft depth samples in 1994. It is anticipated that these samples will be collected in early 2007. As shown in Figure 2-1, the six highest total VOC concentrations in the 30-ft deep soil gas samples collected in 1994 were detected at the first round locations 3, 4, and 19, and second round locations 9, 10, and 11. For comparison purposes, background soil gas VOC and tritium soil samples will also be collected from two additional locations in an area approximately 600 feet southwest of the southwest corner of the landfill that is not believed to be impacted by anthropogenic activities. Actual background sampling locations will be selected during the sampling event.

Each soil gas and soil sample will be identified with a unique location identification number, as specified in Table 3-1. Duplicate soil gas and tritium samples will be collected from the 30-ft depths at second round locations 10 and 11 (Figure 2-1) where the highest soil gas VOC concentrations were detected in 1994. In addition, one aqueous tritium equipment blank (EB) sample will be collected on each day that drilling and sampling occur. All data will be reviewed and validated according to "Data Validation Procedure for Chemical and Radiochemical Data," - Administrative Operating Procedure (AOP) 00-03, Rev. 01 (SNL/NM December 2003).

Table 3-1 also correlates original sample locations from the Phase 2 RFI Active Soil Gas sampling events with the proposed locations for the current samples. Sample location coordinates shown in the table utilize the same MWL coordinate system that was used back in 1994, and are based on distance and relative direction from the northwest corner of the landfill.

3.2 Radon Track Etch Sampling

As shown on Figure 2-1, radon levels around the perimeter of the MWL will be measured using Track Etch radon detectors. A total of 10 detectors will be placed at corners and midpoints of the future perimeter fence that will be constructed once the final MWL cover has been constructed. For comparison purposes, two additional detectors will also be placed in the area at which the soil gas VOC and tritium background samples will be collected. These detectors will remain in place for one quarter (three months), and at the end of that period will be returned to the manufacturer for analysis.

Table 3-1
Summary of Soil Gas VOC and Tritium Soil Sample IDs and Sample Depths

Phase 2 RFI Active Soil Gas Sampling Location (Figure 2-1)	MWL Coordinate Locations	Borehole ID	VOC Soil Gas Sample ID	Tritium Soil Sample ID	Sample Depths (ft below original landfill surface)	VOC Soil Gas Duplicate Sample ID	Tritium Duplicate Soil Sample ID
First Round, Location #3	100S, 10W	MWL-DP1	MWL-DP1-10-SG MWL-DP1-30-SG	MWL-DP1-10-S MWL-DP1-30-S	10 ft 30 ft	NA	NA
First Round, Location #4	150S, 10W	MWL-DP2	MWL-DP2-10-SG MWL-DP2-30-SG	MWL-DP2-10-S MWL-DP2-30-S	10 ft 30 ft	NA	NA
First Round, Location #19	225S, 207E	MWL-DP3	MWL-DP3-10-SG MWL-DP3-30-SG	MWL-DP3-10-S MWL-DP3-30-S	10 ft 30 ft	NA	NA
Second Round, Location #9	200S, 75E	MWL-DP4	MWL-DP4-10-SG MWL-DP4-30-SG	MWL-DP4-10-S MWL-DP4-30-S	10 ft 30 ft	NA	NA
Second Round, Location #10	150S, 75E	MWL-DP5	MWL-DP5-10-SG MWL-DP5-30-SG	MWL-DP5-10-S MWL-DP5-30-S	10 ft 30 ft	MWL-DP5-30-SG-DUP	MWL-DP5-30-S-DUP
Second Round, Location #11	100S, 75E	MWL-DP6	MWL-DP6-10-SG MWL-DP6-30-SG	MWL-DP6-10-S MWL-DP6-30-S	10 ft 30 ft	MWL-DP6-30-SG-DUP	MWL-DP6-30-S-DUP
NA	Background location #1 approximately 600 ft SW of MWL[1]	MWL-DP7	MWL-DP7-10-SG MWL-DP7-30-SG	MWL-DP7-10-S MWL-DP7-30-S	10 ft 30 ft	NA	NA
NA	Background location #2 approximately 600 ft SW of MWL[1]	MWL-DP8	MWL-DP8-10-SG MWL-DP8-30-SG	MWL-DP8-10-S MWL-DP8-30-S	10 ft 30 ft	NA	NA
Equipment Blank	NA	NA	NA	MWL-EB1 MWL-EB2	NA	NA	NA

Table 3-1 (concluded)

Summary of Soil Gas VOC and Tritium Soil Sample IDs and Sample Depths

[1]Actual location to be determined in the field.

DP	= Direct push
DUP	= Duplicate
E	= East
EB	= Epuipment blank
ft	= foot, feet
ID	= Identification
MWL	= Mixed Waste Landfill
NA	= Not applicable
RFI	= RCRA Facility Investigation
RCRA	= Resource Conservation and Recovery Act
S	= Soil, south
SG	= Soil gas
SW	= Southwest
VOC	= Volatile organic compounds
W	= West

4.0 *Data Quality Objectives*

The main data quality objective (DQO) is to produce representative, accurate, and defensible soil gas VOC, tritium, and radon analytical results to support the monitoring objectives. This SAP is designed to ensure that soil-gas and soil sampling procedures are consistent with past practices and produce defensible analytical results that can be compared to historical results. This DQO will be accomplished through the implementation of standard field methods, analytical procedures/methods, and data validation and evaluation protocol consistent with procedures that have been utilized for the collection of soil gas samples at other SNL/NM sites.

4.1 Data Accuracy

Proper sampling procedures such as purging, preparation of sampling containers, and use of quality assurance/quality control (QA/QC) samples such as blanks will help to reduce random and systematic sampling error or bias. Accurate estimates of contaminant concentration can be reliably obtained through use of qualified laboratories, appropriate analytical methodologies, and effective QA/QC procedures. These measures along with consistent implementation of this SAP should satisfy the DQO for accuracy.

4.2 Data Consistency and Compatability

To produce comparable analytical data, QA/QC procedures used to collect future soil gas VOC and tritium soil samples must be comparable with procedures used to collect historic soil gas VOC and tritium in soil moisture samples. Data consistency and comparability will be achieved through implementation of this SAP, which defines field and laboratory procedures designed for this purpose. Consistency in methods and procedures will be maintained in the following areas to ensure that future soil gas VOC and soil tritium sample data are consistent and comparable to historic data sets:

- Field sample collection and management
- Use of an off-site contract laboratory selected by the SNL/NM Sample Management Office (SMO) that complies with the SMO analytical laboratory statement of work (SOW)
- Analyzing soil gas VOC samples by EPA Method TO-14 (EPA January 1999) and soil tritium samples by EPA Method 906.0 (EPA August 1980). Radon measurements around the MWL perimeter will be completed with Track Etch radon samplers.

- Utilizing soil gas VOC and tritium soil moisture analytical data review and validation procedure "Data Validation Procedure for Chemical and Radiochemical Data," Administrative Operating Procedure (AOP) 00-03, Rev. 01 (SNL/NM December 2003)

4.3 Data Verification and Validation

After soil gas VOC and tritium analytical results are received from the laboratory, the SNL/NM SMO will review the laboratory report for completeness and conformance to the performance criteria, and arrange for data validation. If problems are noted that require corrective action during these verification and validation reviews, corrective action will be implemented as defined in the analytical laboratory SOW. The scope of the data verification and validation process addresses field sample management and custody requirements, as well as adherence to QA/QC requirements by the off-site laboratory performing the analyses. These processes are discussed in more detail in Section 5.0.

5.0 *Investigation Methods, and Monitoring and Sampling Program*

This section describes the field and laboratory measures to be taken in producing soil gas VOC, tritium, and radon analytical results that meet the DQOs presented in Section 2.0. Prior to initiating soil gas and soil sampling, field personnel will make sure that all necessary equipment is functioning properly in accordance with applicable FOPs and that the necessary arrangements have been made with the SMO and off-site analytical laboratory for sample shipment and analysis. As appropriate, operating procedures will be reviewed and support personnel will be notified.

5.1 Soil Gas VOC Sampling

Soil gas VOC sampling will generally be conducted in accordance with procedures specified in SNL/NM Field Operations Procedure (FOP) 94-21 (SNL/NM March 1994). Soil gas VOC samples will be collected by using truck mounted direct push sampling equipment provided by a commercial drilling company. This equipment will initially be decontaminated at the SNL/NM decontamination pad in Technical Area III prior to commencement of sampling activities at the MWL. The decontaminated equipment will then be taken to the first sampling location at the landfill and sampling activities will commence. At each sample location, a reusable drive-point fitted with a polyethylene tube will be attached to steel drive pipe, and the tip and drive pipe will be driven to the desired sampling using a hydraulic hammer. Once the sampling depth has been reached, the drive pipe will be retracted approximately 3 to 6 inches to create a void between the tip and pipe, and expose the sampling equipment to a short section of open borehole. The vacuum pump will be activated to extract soil gas from the sampling port. The stream of extracted soil gas will be screened with a photoionization detector (PID) instrument containing an ultraviolet lamp with an ionization potential of 11.8 electron volts. PID readings will be monitored during purging and recorded in the fieldbook or on a sampling form once they have stabilized to within plus or minus 10 percent.

When the PID readings have stabilized, the soil gas sample will then be collected in a 6-liter SUMMA canister. The canister will be filled with soil gas, the valve will be closed, and the canister will be shipped back to the laboratory with an analysis request/chain-of-custody form containing the sample identification number, sample location, date and time, depth, and ambient pressure. The canisters require no special preservation during transport and storage. The soil gas samples will be analyzed for VOCs by EPA Method TO-14.

After each soil gas sample is collected, all field equipment used in the process will be removed from the borehole and decontaminated by washing with Alconox and distilled water. The polyethylene sample tubing will be completely purged with nitrogen gas after each soil gas sample is collected. After purging, the tube will be checked with the PID to ensure that it has been completely evacuated of VOCs.

5.2 Tritium Soil Sampling

Following completion of collection of the soil gas VOC sample in a particular interval, the direct push drive pipe and drive point used for collection of the soil gas sample will be withdrawn from the borehole. The sampling equipment will again be decontaminated, and a 2-inch outside diameter (OD) by 2-ft long stainless steel split spoon sampler will be attached to the end of the drive pipe. The sampler and drive pipe will then be inserted back into the borehole and pushed down to the designated sampling depth at the bottom of the borehole. The split spoon sampler will then be hydraulically driven downward two feet into the undisturbed soil to fill the sampler. The drive pipe and sampler will be retrieved to the surface, and the soil will be transferred to the appropriate sample container. Approximately two liters of soil are required by the laboratory for a soil moisture tritium analysis. A 2-inch OD by 2-ft. long sampler will retrieve approximately 1 liter of soil, so at a minimum a second two-foot long run will be required to retrieve additional soil. If the split spoon sampler is not completely filled during each two-foot sampling run, additional runs will be made until the required volume of soil is obtained. The filled sample containers will be immediately placed in a sampling cooler and shipped to the offsite commercial laboratory for analysis by EPA Method 906.0.

The tritium EBs will be collected by pouring deionized water through a decontaminated split spoon sampler, collecting the rinsate in sample containers, and analyzing the water for tritium by EPA Method 906.0.

Soil gas VOC and tritium soil sample requirements are summarized in Table 5.1. If the borehole remains open following removal of the drilling equipment, it will be backfilled with bentonite chips. A small amount of water will be added to the borehole to hydrate the chips, if they are used.

Table 5.1
Soil Gas VOC and Tritium Soil Sample Requirements

Quantity	Container	Matrix	Parameter	Preservative
18	6-Liter SUMMA canister	Soil Gas	VOCs (EPA Method TO-14)	None
18	(2) 1-liter wide mouth poly	Soil	Tritium (EPA Method 906.0)	None
2 or 3 (depends on number of days in the field)	(1) 250 ml. amber glass	Water	Tritium (EPA Method 906.0)	None

EPA = U.S. Environmental Protection Agency
ml. = Milliliter
VOCs = Volatile organic compounds

5.3 Radon Sampling

Track Etch radon detectors will be used to monitor potential Radon flux that may be emanating from the MWL once the final cover has been installed. These detectors consist of a piece of plastic material which can register alpha particles that hit it. This alpha radiation, which comes from radon and its progeny does microscopic damage to the surface of the plastic. At the end of the monitoring period, the exposed detectors are returned to the laboratory from which they were obtained for analysis. The damaged area is then chemically etched, and the damaged area is enlarged and seen as tracks. The tracks can be counted and related to the radon concentration in the air in which the detector was exposed.

As shown on Figure 2-1, the detectors will be placed at 10 locations around the the MWL perimeter fence. The detectors will be placed on MWL perimeter fence posts at a breathing level height of approximately six feet above the ground surface. In addition, for comparison purposes two additional detectors will also be placed in the area at which the soil gas VOC and tritium background samples will be collected. These detectors will remain in place for one quarter (three months) to collect the initial round of baseline data, and at the end of that period will be returned to the manufacturer for analysis. A report summarizing results of the analyses of the detectors will be prepared and transmitted to the NMED for review.

5.4 Laboratory Analysis and Data Review

Laboratory analysis and data review includes the methods and procedures used to obtain the soil gas VOC and tritium results and confirm the quality of the information. All soil gas and tritium samples will be submitted to an off-site analytical laboratory that was selected by the SMO and follows the SMO SOW. The soil gas VOC and tritium samples will be analyzed using EPA Methods TO-14 and 906.0, respectively. The off-site laboratory is responsible for implementing the requirements of the method, including analytical methodology, target analytes for quantification, and internal QA/QC procedures. After the analytical results are received from the laboratory, the SMO will review the laboratory report for completeness and conformance to the current off-site commercial laboratory performance criteria. If problems are noted that require corrective action, corrective action will be implemented as defined in the analytical laboratory SOW.

5.5 Data Validation

After the data verification review is completed, the SMO will arrange for the validation of the data by an outside contractor. The scope of the data validation process addresses field sample management and custody requirements, as well as adherence to the analytical method and internal laboratory QA/QC requirements by the off-site laboratory performing the analyses. The purpose of data validation is to determine the usability and establish the defensibility of the numerical results. Data qualification is based upon review of laboratory-supplied QC data, the specific QC criteria, and the DQOs identified in the procedures for EPA Methods TO-14 and 906.0. Data validation will be conducted according to the requirements of Administrative Operating Procedure (AOP) 00-03, Rev. 01, "Data Validation Procedure for Chemical and Radiochemical Data." (SNL/NM December 2003) All associated data validation reports will be provided along with the results for each sampling event.

5.6 Data Management and Reporting

Technical evaluation and reporting activities will be initiated after data validation is completed. Analytical results of the future soil gas VOC and tritium soil samples, and results of the radon Track Etch measurements will be summarized and reported in investigation report that includes the elements specified in Section X.C of the NMED Compliance Order on Consent (NMED April 2004).

5.7 Records Management

Records associated with the soil gas VOC, tritium, and radon sampling effort include this SAP, field documentation, laboratory analytical results, data validation reports, and technical data evaluations. These records will be maintained at the SNL/NM Customer Funded Records Center.

6.0 Schedule

6.1 Soil Gas VOC and Tritium Sampling, Analysis, and Reporting

It is anticipated that the soil gas VOC and tritium soil samples will be collected in early 2007. Preparations for field work and sample collection activities are expected to take approximately one week. Approximately two months will be required for sample analysis (assumes normal [21 working day] laboratory turnaround), SNL/NM SMO contract verification and data validation, and data entry into an electronic database. Once the validated results are entered into the database, a report summarizing the results of the sampling will be prepared and submitted to the NMED for review. The report production, peer review, and transmittal process will require approximately six weeks. The total time from start of field work preparations through transmittal of the final report to NMED is anticipated to be approximately 3.5 months.

6.2 Radon Track Etch Sampling, Analysis, and Reporting

Radon track etch samplers will be placed at ten locations on the perimeter fence that will be installed once the MWL final cover has been completed, and at two background location southwest of the landfill. These samplers will remain in place for three months to obtain one full quarter's worth of data, and will be returned to the manufacturer for analysis at the end of this period. Approximately one month is required for detector analyses and reporting by the manufacturer. A report summarizing the results of the radon track etch sampling will then be prepared and submitted to the NMED. The report production process and transmittal is also anticipated to take approximately six weeks. Therefore, total time from deployment of the track etch samplers in the field to submittal of the final summary report to NMED is anticipated to be approximately 5.5 months.

7.0 References

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